(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 473 142 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **91114470.7**

(51) Int. Cl.5: **G06K 15/12**

(22) Date of filing: **28.08.91**

(30) Priority: **28.08.90 JP 224369/90**
29.06.91
09.07.91

(43) Date of publication of application:
04.03.92 Bulletin 92/10

(84) Designated Contracting States:
DE FR GB

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(54) Method for smoothing an image.

(57) This invention relates to a method for forming an image constituted of a dot matrix and is applied to a printer, such as a laser printer of al LED printer, or to a bit map display unit such as a CRT display, and more particularly to a method for smoothing the image by smoothing stairsteps included in the image to obtain a high resolution.

The method comprises steps of dividing a pixel (A, B) into a plurality of subpixels (*1...*3) along a vertical scanning line or a horizontal scanning line, and of reversing a signal for a subpixel (*1...*3) in accordance with a reversion signal to smooth the image as desired. The reversion signal may be provided by subjecting a specific pixel to a boolean operation, a conjunction or disjunction operation, with the adjacent pixels next to the specific pixel. The reversion signal may also be provided by steps comprising: generating, in advance, a set of four bordering data which represents the relationship of a specific pixel with bordering pixels, which bordering data are generated by subjecting the specific pixel and the four bordering pixels to a nonequivalent boolean operation, respectively, detecting the location of the stairstep and recognizing the style of the stairstep referring to the relationship among the bordering data for the pixels located along the vertical or horizontal line, and measuring the length of the level pixels adjoining with the stairstep.

FIG. 4 (a)

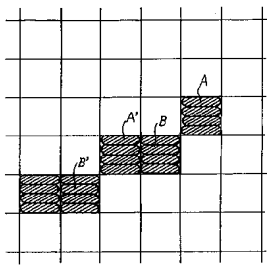
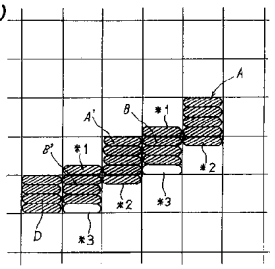


FIG. 4 (b)



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BACKGROUND OF THE INVENTION

[Field of the Invention]

This invention relates to a method for forming images with dot images in a matrix used for a printer, an light emitting diode (LED) printer, or in such a bit map display unit as a cathode ray tube (CRT), and more particularly to improve the images by smoothing stairsteps included in the dot images.

[Description of the Prior Art]

A prior art shows that a laser printer forms a picture element pattern or pixel pattern on a photosensitive drum along its coaxial scanning line in a matrix by scanning repeatedly laser beams modulated video data sent serially from a image controller.

Another prior art teaches that a dot printer such as an LED printer forms pixel pattern in a matrix on a recording member, a photosensitive drum for example, moving relatively vertically, by means of forming pixel such as LED disposed along the coaxial scanning line, which is controlled to emit simultaneously in the full line or successively in a block after blocks.

In either printers, the pixels are arrayed in an n x m matrix to form characters or pictures. Letters such as O and V consisted of curvatures or diagonals, therefore, is formed in stairstep edges which damage the quality of the picture.

To overcome the defects, in the laser printers which forms pixel patterns by scanning the modulated laser beams along the scanning line, attempts for smoothing the stairsteps are disclosed to form the smaller dot size by reducing the output energy for the pixels at the diagonal edges (Laid Open Pat. Apln. 60-139072); or to modulate narrower the width of the output laser beams and to print deviately the small dots within the normal dot area.

In the LED printers, on the other hand, arrayed with the diodes in a line, the diodes are disposed with a fixed distance along the scanning line. The LED's, further, are arranged in a modular tip with an n units of diodes which results in to control the scanning line with the n units or the full line. It is, therefore in the LED printers, hard to adopt the above techniques which changes the dot size and shifts deviately the smaller dot.

In a LED printer, therefore, which outputs video image with a line unit, a technique for smoothing stairstep edges is disclosed a method for arranging pixels coordinately so that each pixels shift in every scanning lines within a suitable distance to dispose the pixels diagonally along the vertical scanning line (Pat. Publn. 62-24987).

In the prior technique, however, as the pixels shift in the full scanning line, it is hard not only to obtain a smoothed character, but also to absorb a steep stairstep even if the elements arranged by logical adjunction.

To overcome the defects above, a technique is disclosed to replace pixel in question with one of narrower pixels which are made coordinately narrower in either ways along the scanning line or the vertical scanning line (Laid Open Pat. Apln. 2-112966).

In the previous prior technique, the replacement of the specific pixel in question is made referring with a reference pixel pattern among four each compensation sub-cells prepared in narrower element in the coordinate ways. The prior technique, in the LED printer, is able to provide narrower dots in the vertical way controlling the emitting time of the LED array. Because the LED is disposed in a fixed distance, the pixel has to be controlled the light intensity to make the pixel narrower in the scanning way. As described above, because the LED's is combined in a tip with a plurality of diodes, it is substantially hard to control the light intensity for one by one.

U.S. Pat. 4,437,122 shows a smoothing technique that a center pixel is replaced with a subpixel which is divided coordinately in 3 x 3, referring the surrounding pixels. The technique is hard to adopt in LED printers, because the LED can not be divided along the scanning line. Further, the center pixel has to be referred with eight surrounding pixels, and to be matched with the 3 x 3 subpixel combinations, that is, 20 subpixel patterns including their rotation which results in preparing a sophisticated circuit, and in a prolonged processing time. Thus, the technique does not satisfy the needs for faster processing.

Either of prior techniques are consisted of steps, firstly appointing the central pixel in question, secondly comparing the configuration of n x m neighboring pixels with the a lot of templates prepared in advance, lastly smoothing the central pixel according to the template pattern matched. To compare the configuration of the neighboring pixels means that one has to prepare a lots of templates corresponding to the combinations in the n x m matrix. Further, there is a meaningful stairstep to figure such corner as in letters E and F, of which corner must be kept in sharp. To achieve the effective smoothing not to smooth the meaningful stairsteps, one has to prepare other templates for the stairsteps not to be subjected to the procedures which results in providing another memory for the meaningful stairsteps, and in constructing more sophisticated circuit. The large scale of the circuit and the big amount of work for matching delays the process, thus, fail to satisfy the require-

ment for faster processing.

SUMMARY OF THE INVENTION

Considering the defects of prior techniques, it is an object of the present invention to provide an image smoothing method which is able to smooth images easily and accurately without a sophisticated circuit, and with a simple processing.

It is a further object of the present invention to provide an image smoothing method which is able to smooth images, and also to improve pixels acceptable for enlargement of the smoothed data with enhanced resolution.

It is a further object of the present invention to provide an image smoothing method which is able to accomplish the objects, usable for such a dot printer in line as an LED printer.

To achieve the objects, the method is intended that the pixel is divided into P pieces of subpixel along the vertical scanning line, or the horizontal scanning line following the teachings of Pat. Publn. 62-26626, Laid Open Pat. Appln. 60-134660 and so forth, and further, each subpixels is applied with the subpixel signal, either a black signal or a white signal, wherein the subpixel signal is reversed appropriately to form the pixel output.

The present embodiment will be described in detail referring to attached drawings.

The first invention illustrated on Figs. 1 and 2, shows a method for smoothing image adopted the subpixel method for the line dot printer, the LED printer for example, of which picture elements are arrayed along the scanning line.

The feature of the invention is comprised; a constitution of pixel consisting P = 3 or more preferably 5 pieces of subpixels as shown on Fig. 1, in either stages prior to or without image smoothing, in which a smaller number N (N<P) of subpixels are serially applied the subpixel signals to form the pixel for the full line or a unit of n bits to be output; and in the stage of image smoothing, the subpixel signals are applied not only with said subpixels, but also with other pixel or pixels to reverse its signal(s) referring the specific pixel in question with the preceding and succeeding pixels to form the output pixel.

The smoothing procedure, as shown on Fig. 1, is made by reversing the subpixel signal(s) so that the black pixel(s) seemingly may be added or reduced vertically within the specific pixel; or as shown on Fig. 2(a), so that the black pixels seemingly may be shifted vertically to the next pixels located on the preceding or succeeding lines, or beyond the specific pixel; or as shown on Fig. 2(b), so that the black pixel(s) seemingly may be reduced vertically within the specific pixel, or may be added so that the pixel(s) seemingly shift to the next pixel to form a bold pattern.

The smoothing procedure, as shown on Figs. 1 and 2, comprises following steps. Supposing the printer outputs a pixel with 5 subpixels P1 through P5 divided vertically as seen on Fig. 1(a), the normal pixel b2 consists of 3 subpixels in the middle as a black dot, remaining the upper and bottom subpixels as vacant or white pixels. The 3 subpixels among 5 subpixels will be applied the subpixel signals, and be considered as a 100% intensity pixel.

To make the image smoothing following the pixel information next to the specific pixel, subpixels P1 and P4 may be reversed to shift seemingly the black dot close to the preceding pixel as in b1, or subpixels P2 and P5 may be reversed to shift seemingly the black dot close to the succeeding pixel as in b3. Thus, 3 patterns of dot, b1, b2 and b3, are available. If the reversion of subpixel P2 alone, or subpixels P2 and P4 is taken place, reduced pixels of b4 (67% intensity) and b5 (33% intensity) are obtainable.

The arrangement of subpixels b1 through b5 allows to print enhanced characters with a smoothed stairsteps of the diagonal or round lines. Letter X, for example, can also be avoided a bold crossing, if the pixel b4 (67% intensity) is chosen for the central crossing.

The instance above shows an example that the P is taken as 5, and the N is taken as 3 which provides vacant subpixels at the top and bottom. The vacant subpixels allow the image smoothing procedure with reversion. The vacant subpixels, on the other hand, form the pixel thin when the pixel does not be subjected to the image smoothing. Further, the vacant subpixels provide a clearance between the pixels preceded and succeeded, of which clearance prohibits to paint all over a certain area. The clearance, in some cases, makes the pixels vertically apart, and makes character coarse which may interrupt to achieve the image smoothing.

In the events above, the reversion of subpixel may not be limited within a pixel, but may be extend to the pixels adjoining vertically to the specific pixel as shown on Fig. 2(a). Up to two bottom subpixels of the upper pixel may be reversed to shift seemingly to break the ceiling (b6), and to oppositely the pixel (b12), that is, other 4 pixels (b6, b7, b11 and b12) provide a dense and fine image smoothing.

Further, it is worthwhile to expand, by reversing any subpixel(s) of the pixels above, the pixels up to 35 patterns in all including such patterns as 33% dots (b13, b14), 67% dots (b15, b16), 100% dots (b17 or b6, b18), 133% dots (b19, b20), and 167% dots (b21, b22).

Figs. 3 through 5 show the second procedure

of the image smoothing for the apparatus which adopts the reversion process.

The feature lies on that the specific pixel next to a boundary where a pixel changing white to black, or black to white along a desired scanning line, and the reference pixels next the specific pixel on the preceding or succeeding scanning line are subjected to boolean operation, conjunction and disjunction, to smooth the specific pixel, the reference pixel(s) and adjacent pixel(s) thereof.

The specific pixel next to the boundary, therefore, is not limited to the black pixel, but also includes the white pixel.

The present invention also includes the case that the number of subpixels P in a pixel equals to the number of the normal subpixels N in the subpixels P, and the case previously described that N < P as well.

Fig. 3 shows a practice for replacing black pixel(s); in which Fig. 3(a) for a stairstep to be smoothed, and Fig. 3(b) smoothed pixels. The specific pixel A is detected where a series of white pixels (0) turn to a black pixel (1). The specific pixel A is subjected conjunction operation with the reference pixels E and F next to the specific pixel A and located at preceding or succeeding scanning line to assign subpixels *1 and *2 to be reversed. A subpixel *1' is produced simultaneously with the subpixel *1.

Following the steps above, the specific pixel F is detected where a series of black pixels (1) turn to a white pixel (0). The specific pixel F is subjected conjunction operation with the reference pixels A and G next to the specific pixel F located at preceding or succeeding scanning line to decide subpixels *3 and *4 to be reversed. A subpixel *4' is produced simultaneously with the subpixel *4. The boolean operation is described as follow:

*1 : A (0→1)∧E∧F
*2 : A (0→1)∧E∧F
*3 : F (1→0)∧A∧G
*4 : F (1→0)∧A∧G

Fig. 4 shows another practice of the second procedure of the present invention; in which Fig. 4-(a) for stairsteps to be smoothed, and Fig. 4(b) smoothed pixels. Following the steps above, the specific pixels A and A' are detected where a series of white pixels (0) turn to a black pixel (1). The specific pixel A and A' are subjected conjunction operation with the reference pixels B and B' next to the specific pixel A and A' and located at preceding or succeeding scanning line to assign subpixels *2 to be reversed.

Succeedingly, the specific pixels B and B' are detected where a series of black pixels (1) turn to a white pixel (0). The specific pixels B and B' are subjected conjunction operation with the reference pixels A, A' and D next to the specific pixels B and B' located at preceding, succeeding or the same scanning line to assign subpixels *3 to be reversed from black to white subpixels. The boolean operation is described as follow:

*1 : A, A' (0→1)∧B
*2 : B, B' (1→0)∧A (A')
*3 : B, B' (1→0)∧D (A)∧A (A')

Fig. 5, further, shows another practice of the second procedure of the present invention which reverses subpixels a, b and g located at subpixel lines P13 and P14 of the lower subpixels on the same scanning line I, and subpixels c through g located at subpixel lines P21 and P22 of the upper subpixels on the succeeding scanning line II.

The specific pixel A is detected where a series of white pixels (0) turn to a black pixel (1) on the same scanning line I. The specific pixel A is subjected to conjunction operation with the reference pixels E and F next to the specific pixel A located at succeeding scanning line II. The specific pixel C is detected where a series of black pixels (1) turn to a white pixel (0) on the same scanning line I. The specific pixel C is subjected to conjunction operation with the reference pixels G and H next to the specific pixel C located at succeeding scanning line II to provide subpixels to be reversed, preceding subpixel b1 and succeeding subpixel b2 on the subpixel line P13, and 2 bits of subpixels on the line P14, preceding subpixels al and a2, and succeeding subpixels g1 and g2.

Succeedingly, the specific pixels F and G are detected on the succeeding scanning line II. The specific pixels F and G are subjected to conjunction operation with the reference pixels A, B, and B, C respectively next to the specific pixels F and G located on the scanning line I to provide subpixels to be reversed, one each bit of subpixels d and f at the subpixel line P22, 2 each bits of subpixels c, c/e, and c/e, g at the subpixel line P21 respectively. As the subpixel c/e is subjected to conjunction operation twice, the disjunction operation is subjected to reverse the subpixel c/e.

Following the present invention, firstly, the specific pixel is detected, where a series of white (black) pixels turn to a black (white) pixel on the scanning line, and, secondly, is subjected to boolean operation, conjunction and disjunction, with reference pixels next to the specific pixel located at preceding or succeeding scanning line to produce subpixel(s) to be reversed. Thus, the image smoothing is achieved easily with a simple boolean operation under a simple instructions, to provide higher resolution. The reversion process is effective especially for the LED printer of which writing head is arrayed in a line.

The third procedure of the present invention shown on Figs. 6 through 9B features to smooth an image providing boundary data which specify the

relationship between every pixels and pixels having a common boundary.

The prior techniques described above have disclosed that the specific pixels is smoothed by matching the n x m neighboring pixels with a number of patterns prepared in advance. The first and second procedures of the present invention features to detect the specific pixel, and then the specific pixel is subjected to the boolean operation, conjunction or disjunction, to reverse the subpixels for smoothing.

The third procedure of the present invention features, of which reversion process is similar to the first and second procedures of the present invention;
firstly to provide the bordering data which specify the relationship with the four pixels having a common horizontal or vertical boundaries (called as bordering pixels, hereinafter) for all pixels forming the image pattern; secondly, to recognize the location and style of stairstep subjecting to boolean operation with bordering data to find out a certain relationship; thirdly, to count length of level pixels; and finally, to smooth the pixels reversing the subpixels using those data.

The third procedure of the present invention is a quite unique one to approach for the image smoothing which provides the bordering data for every pixels specifying the relationship with bordering pixels, without firstly identifying the specific pixel nor the reference pixels.

It is preferable but not to be limited for providing the bordering data, that is, the all pixels forming the image pattern are subjected to nonequivalence operation, or exclusive-OR with the four bordering pixels next to the specific pixel horizontally and vertically, obtaining four bits of binary data for every pixels.

It is, further, preferable but not to be limited for recognizing the stairstep that a pair of bordering data of adjoining pixels located on the horizontal or vertical line with a common boundary are extracted to verify if there is a stairstep between the pixels, or whether or not three equations described below are satisfied, and if so, to classify what style of the stairstep to be modified.

It is, further, preferable for reverse the subpixels concerned that length of level pixels is counted for selecting a reversion code specifying which of subpixel(s) is reversed. The reversion code table shows that the reversion code, 1 or 2, is apportioned for each pixels apart from the stairstep, and for each stairsteps having the length of level pixels. The reversion code table offers a simpler circuit for faster processing with higher accuracy.

The third embodiment of the invention will be described as follow:

1) Generating Bordering Data

The pixels on (n-1)th, (n)th and (n+1)th line, as shown on Fig. 6(a), are shifted to be read one after the other. As shown on Fig. 6(b), a specific pixel Bn, for example, is subjected nonequivalent or exclusive-OR (E-OR in short) operation with the bordering pixels, An, Bn-1, Cn and Bn+1, having a common vertical or horizontal border line with the pixel Bn, which generate 4 bits of binary values denoted as do, d1, d2 and d3.

The boolean values, do, d1, d2, d3, will be generated for all pixels, a through g, for example as shown on Fig. 6(c). The E-OR boolean value takes "1" if the two operands (pixels) differs each other (white-black, or black-white pixels), otherwise, takes "0" for the same operands (white-white, or black-black pixels).

It is notable, therefore, that the color itself does not be concerned, but the value tells the relationship between the pixels. Taking f and g as an example, though the pixels indicate different colors, white for f, and black for g, the values, d0, d1, d2, d3, for the pixels are the same (0, 0, 0, 0), because the pixel f (g) is next to the same white (black) bordering pixels. That is, the value tells us the relationship with bordering pixels.

2) Detecting the Stairstep and Recognizing the Style

To detect stairstep, arbitrary at least three sets of the bordering data for the adjoining pixels on a horizontal or vertical line are extracted and verified if the data satisfy the Equs. 1) through 3). If so, the stairstep is recognized to which of style does it belong. The styles of the stairsteps are illustrated on Figs. 7A and 7B, styles (1) to (4), and (5) to (8), respectively.

The boolean values, d0 through d3, for the pixels beyond the concerned pixel line, for the pixels on (n+1 or n+2)th line for example, are not extracted for the stairstep detection. Because the relationship with the adjoining pixels on the same line is concerned to detect the stairstep, and because the verification of the bordering data of pixels on the concerned line results in considering the states of pixels on three lines which is included upper and lower lines, the bordering data for one line, therefore, are enough to detected the stairstep.

As the third procedure of the present invention generates firstly the bordering data as for the relationship with the bordering pixels, and detects the stairstep together with its style by the relationship in the bordering data of adjoining pixels on the same horizontal or vertical line, the present invention is able to smooth the images with the simpler

circuit, faster processing, and higher resolution than that of the prior techniques which aught to match the n x m matrix data with the a number of patterns.

The boolean operation for detecting the stairstep is, firstly, subjected to extract a pair of bordering data for the pixels adjoining horizontally or vertically, denoted d0A, ..., d3A and d0B, ..., d3B, and assuming (α and β) as any one of combinations among (0, 1), (1, 2), (2, 3) and (3, 0), and to see if

$$(d\alpha A, d\alpha B) = (d\beta A, d\beta B) = (0, 1), \quad \text{Equ. 1)}$$

and assuming τ or δ are any other numerals designating the bordering data for the pixel A taken in Equation 1),

$$d\tau A = d\delta A = 1. \quad \text{Equ. 2)}$$

Secondly, the operation is subjected to extract the bordering data for the pixel C, which is opposite to the pixel B next to the pixel A, and assuming τ or δ are any other numerals taken in the Equation 1), and to see if

$$(d\tau C, d\delta C) = (1, 0) \text{ or } (0, 1). \quad \text{Equ. 3)}$$

If the relationship among the bordering data for the three pixels, A, B, and C, satisfy simultaneously at least the three equations, Equs. 1), 2) and 3), the boundary between A and B is deciphered as the stairstep.

In the case of letters E or F, therefore, because a rectangular has pixels more than two, there is no means to be recognized as a stairstep.

Further, as seen on Fig. 9B (A), the stairstep (a) does not be deemed as a stairstep, because there is no level pixel succeeding the stairstep. The stairstep (a), therefore, will not be subjected to the smoothing procedure.

Therefore, there is no need to consider beyond the styles as shown on Figs. 7A and 7B, which will be four styles for each direction of horizontal and vertical ways, totaling eight styles. The detecting and the recognizing procedures are so simple to subject four bits of binary values of the bordering data for the adjoining pixels to analyze relationship therebetween by the boolean operation that the procedures are able to be treated with a simple circuit and processing without worrying about the color of the pixels, white or black, without handling in a block unit as used to do in the prior techniques.

3) Assigning Reversion Code

The length of level pixels is counted. The one of reversion codes, 1 or 2, as show on Fig 9B (A), is assigned for each pixels referring to the distance from the stairstep, and the length of level pixels.

To count the length, as shown on Fig. 9B (A), is to be counted the level pixels succeeding or preceding the stairstep. The pixel at the stairstep does not be included in the length. The length for the stairstep (e): L = 1; for the stairsteps (c) and (b): L = 4; for the stairstep (d): L > 5; and the stairstep (a): L = 0 which is not subjected to the smoothing procedure.

Referring to the reversion code table shown on Fig. 9B (A), as for the stairstep (d) of which the length of level pixel is more than five, the reversion code for the pixel at the stairstep of which distance from the stairstep is zero is assigned as 2, and the reversion code for the pixels located at the distance 1 pixel and 2 pixels from the stairstep are respectively assigned as 1.

4) Assigning of Subpixel(s) to be reversed

Referring to the reversion data table (a) for laser beam printer (LBP in short), and table (b) for LED shown on Fig. 8, reversion data is selected as per the stairstep style and the reversion code.

The reason why the tables are provided is to collect the cases as per the reversion data, without generating the reversion data for each stairstep styles and reversion codes, to make the circuit simple.

The reversion data illustrates which part of subpixel(s) will be reversed. The LBP, which is able to divide the beam along the scanning line, takes the reversion data of which subpixels are divided vertically as shown on Table (a) of Fig. 8. The horizontal stairsteps styled (1) through (4) will be collected in a category for each reversion codes, 1 and 2. And vertical stairsteps styled (5), (7) and (6), (8) will be collected in other categories for each reversion codes. The table (a) illustrates six reversion data for three categories of stairstep styles, and for each reversion codes. The shadowed subpixel(s) indicates the subpixel(s) to be reversed.

The reversion data table (b) is prepared for the LED of which subpixel is able to be divided horizontally along the vertical scanning line. The eight styles of the stairsteps drop in three categories for each reversion codes, totaling six reversion data, as well.

The tables show that in the stairstep styled as (1) or (3) for the LED printer, for example, if the pixel is assigned the reversion code as 1, the bottom subpixel of the pixel will be reversed, and if the code as 2, the lower two subpixels will be reversed, and so forth.

5) Reversion of Subpixel

Following the signal obtained by the reversion data table, the subpixel(s) of the pixel is reversed to form the output video data.

In the LED printer, for example, which output the image repeatedly in four times for a pixel according to the video data, it is quite enough to reverse the subpixels corresponding to the reversion data just before delivering the video data to the printer, which results in achieving with a simple smoothing circuit, and in a shorter processing time than the sophisticated circuit used to be.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 and 2 are explanatory views for describing the first image smoothing procedure of the present invention, in which Figs. 1(a) and (b) illustrates the basic concept of the procedure; and Fig. 2(a) and (b) illustrate another modified procedure, that the reversion is made up to subpixel(s) next to the specific pixel to be seemingly shifted.

Figs. 3 through 5 are explanatory views for describing the second image smoothing procedure of the present invention, in which Fig. 3 illustrates the procedure reversing especially subpixel(s) of white pixel alone; Fig. 4 illustrates the procedure reversing subpixel(s) of both white and black pixels; and Fig. 5 illustrates another modified procedure reversing up to subpixel(s) next to the specific pixel.

Figs. 6 through 9B are explanatory views for describing the third procedure of the present invention; in which Fig. 6 illustrates the procedure to generate bordering data and those examples; Fig 7A illustrates styles of horizontal stairsteps and those bordering data; Fig. 7B illustrates styles of vertical stairsteps and those bordering data; and Fig. 8 illustrates reversion data tables for the pixels divided vertical or horizontal subpixels, respectively. Figs. 9A and 9B are views for describing a practical procedure of the present invention applied for an LED printer; in which Fig. 9A illustrates to specify the style of stairstep, and to count length of level pixels; and Fig. 9B illustrates to apportion the reversion code to respective pixels according to the style of stairstep and the length of level pixels referring to a reversion code table, and of which subpixels of stairstep image are reversed to smooth the stairsteps.

Figs. 10 and 11 are explanatory views for describing an LED printer applied the present invention; in which Fig. 10 illustrates a circuit block diagram of the printer head of LED printer; and Fig. 11 illustrates the output pixels formed by the circuit.

Fig. 12 is an illustration describing a circuit block diagram for the first image smoothing procedure.

Figs. 13 and 14 are illustrations describing circuit block diagrams for the second image smoothing procedure; in which Fig. 13 illustrates the whole circuit block diagram; and Fig. 14 illustrates detailed circuit block diagram for apportioning the reversion data, and reversion of the subpixels.

Figs. 15 through 17 are illustrations describing circuit block diagrams for the third image smoothing procedure; among which Fig. 15 illustrates the whole circuit block diagram; Fig. 16 illustrates a detailed circuit block diagram for generating the bordering data; and Fig. 17 illustrates detailed circuit block diagrams for boolean logic unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described in detail with reference to the accompanying drawings. The sizes, materials, shapes, and relative arrangement of respective parts of the embodiment described herein are only descriptive examples and are not intended to restrict the scope of the present invention, unless otherwise noted.

Fig 10 is an explanatory views illustrating a circuit block diagram of the printer head of LED printer applied the present invention, in which the circuit receives n bits of pixels of images to emit sequentially in time sharing attitude to the LED head elements; reference numeral 1 denotes an LED array disposed in a line a plurality of LED tips 1A, 1B, ..., 1M consisted of n bits of LED element 1a, numeral 10 denotes a driving integrated circuits (IC's) for the LED array 1, of which driving IC's consists of a shift register 11 having storage capacity corresponded to the number of LED elements n bits, a latch 12, and a switch 13 having switch elements corresponded to the number of LED elements n bits, wherein switch elements and the LED elements are connected with a printed wiring in a matrix formation.

Reference numeral 4 denotes a block apportioner which shift sequentially the connection between the switch 13 and the LED tips 1A, ..., 1M on receiving every n bits pixel data in the shift register 11.

The circuit functions, firstly, the shift register 11 receives and stores serially the first n bits video data of the pixels from a image smoothing control 53 on receiving a clock signal, upon receiving a latch signal from a control 5, the latch 12 receives and hold the n bits pixel data signals in parallel, and then transfer the signals to open the switch 13 for emitting the LED elements 1a of the LED tip 1A.

Secondly, the shift register 11 receives and stores the second n bits pixel data following to

transference of the first data to the latch 12, the latch 12 receives the second n bits data upon receiving the latch signal from the control 5, and send a block signal through the control 5 to the block apportioner 4 that the latch 12 is ready for working the switch 13, the block apportioner 4, then, shifts the connection to the next LED tip 1B to emit.

The circuit, thus, outputs the pixel data repeatedly for m times up to the LED tip 1M to cover full length of a scanning line.

In the same manner, the circuit controls each of LED tips 1A, ..., 1M (m x 4) or (m x 5) times for the scanning line divided in 4 or 5 subpixels to develop the image as shown on Fig. 11.

Fig. 12 is an illustration describing a circuit block diagram for the first image smoothing procedure. The circuit is connected with an output terminal of video memory (not illustrated) which stores the unfolded image data, and is constituted to receive the video data for a plurality of scanning lines from the video memory, to subject the video data to smooth stairsteps, and to send the data to the shift register 11 of the LED head circuit shown on Fig. 10.

The circuit consist of a pattern memory 51, a decoder 52, and an image smoothing control 53.

The pattern memory 51 receives serially the unfolded video data for the scanning line on receiving a video clock signal, and stores the specific video data ready for transferring to the shift register 11 together with the video data for preceding and succeeding scanning line(s).

The decoder 52 includes a boolean operation unit. The video data in the pattern memory 51 adjacent to the specific pixel, or more particularly, in a matrix RX1 consisting of R pixels in horizontal scanning way and X pixels in vertical scanning way, are subjected to logical conjunction on receipt of the SL signal from the control 53; and some of the subpixels are reversed as desired to form the output subpixel data.

The smoothed data subjected to the reversion procedure are transferred upon receiving the standard clock signal to the n bits shift register 11 of the LED head circuit shown on Fig. 10.

In every transferring the subpixel data to the shift register 11, the decoder 52 on receipt of the standard clock signal subjects the subpixel data in the pattern memory 51 to reverse as desired to smooth the image shifting the RXn matrix sequentially one after the other, while shifting the specific subpixels *1, *2, ..., *n.

The reversion procedure is repeated up to (m)-th RXm matrix for the first line P1, and then return to the first n pixels of the second subpixel line P2, and so forth, until the fifth subpixels line P5 to accomplish the smoothing procedure for the first pixel line as shown Figs. 1 and 2.

Figs. 13 and 14 are illustrations of circuit block diagrams for the image smoothing describing an embodiment of the preset invention for the second image smoothing procedure.

Referring Fig. 13 illustrating the whole circuit block diagram, video data (VDATA) unfolded in an image random access memory (RAM) (not illustrated) are transferred serially to a shift register 104 synchronizing with a video clock (VCLK) signal generated with a VCLK 101, then, the VDATA are converted into N+1 bits parallel data with the shift register 104, and the VDATA are stored in the first address of the first bank of a static RAM (SRAM) 105. The succeeding N+1 bits converted parallel data are stored in the second address, repeating the same until the VDATA for the first scanning line are stored in the first bank of the SRAM 105.

Repeating the same procedure, VDATA for the second line are stored in the second bank, VDATA for the third line are stored in the third bank, and so forth.

All of VDATA for the N lines are stored in the 1st to (N)th bank of the SRAM 105. During the time for preparation VDATA for the (N+1)th line to be stored in the first address of the (N+1)th bank of the SRAM 105, an SRAM control 103 reads sequentially the VDATA stored in the first address of the 1st to (N)th bank on receiving a latch signal, and stores in the latch of a latch & shift 106, ..., 112. Following signal from the SRAM control 103, the VDATA stored in the latch of the latch & shift 106, ..., 112 are loaded into shift registers of the latch & shift 106, ..., 112.

Repeating the same procedure, VDATA for the (N+1)th line are stored in the (N+1)th bank of the SRAM 105 synchronizing with VCLK, and simultaneously to the above, VDATA for the 1st to (N)th lines stored in the SRAM 105 are transferred to latches of the latch & shift 106, ..., 112, and then, VDATA in sift register of the latch & shift 106, ..., 112 are loaded sequentially in an N line shift register 113.

When the SRAM 105 has stored the VDATA for the (N+1)th line in the (N+1)th bank, the SRAM 105 stores, following signals from the SRAM control 103, VDATA for the (N+2)th line in the first bank, VDATA for the (N+3)th line in the second bank, until the 1st to (N)th banks are updated.

Finally, a pixel map (N x 7) consisting of preceding and succeeding adjacent line(s), and 7 pixels including each three preceding and succeeding adjacent pixels is arrayed and stored in the N line shift register 113, as the VDATA transferred from the SRAM 105 updates sequentially the pixel map. Thus, with the pixel map, the image smoothing procedure in an image smoothing unit 120 is ready for boolean operation.

The image smoothing unit is consisted of selectors 121A and 121B for selecting the specific pixel, an AND logic 123 composed of AND logics 122A and 122B, a line counter 124 for selecting a subpixel line of the pixel, delay units 125A and 125B which subjects vacant subpixel(s) to operate reversion, if there is the vacant subpixel(s) between the specific subpixel and the subpixel reversed by the boolean operation, a line counter for selecting the subpixel line, and an OR gate 127 and an AND gate 128 which subjects the subpixel reversed to black to operate disjunction, or the subpixel reversed to white to operate conjunction, wherein the subpixel VDATA passed through the gates are send serially to the LED head circuit.

Referring Fig. 14, the procedure of the image smoothing unit 120 will be described that; firstly, the N line shift register 113 detects the specific pixel A where white pixels (0) turns to a black pixel (1); secondly, following line counter signals i through iv, the selectors 121A and 121B select reference pixel(s) bordering with the specific pixel among the pixels B through M on the preceding scanning line P-1 and succeeding scanning line P+1, or in other words, select the reference pixel(s) among the bordering pixels B through G during the line counter signals i and ii, and among the bordering pixels H through M during the line counter signals iii and iv.

The specific and reference pixels are subjected to conjunction operation with the AND logics 122A and 122B to generate reversion signals as desired. If necessary as described above, with the reversion signal generated with the AND logics 122A and 122B, the delays 125A and 125B generate another reversion signal to form 2 bits sequential reversion signals to fill the vacant pixel.

Thus arranged subpixel signals are sent to the OR gate 127 and the AND gate 128 through the OR units 129A and 129B, wherein the arranged subpixel signals together with the video signals of the specific subpixel from the N line shift register 113 are subjected to boolean operation, disjunction in the OR gate 127 or conjunction in the AND gate 128, to achieve the image smoothing procedure. The smoothed subpixel VDATA are transferred serially up to the shift register 11 of the LED head array 1 shown on Fig. 10.

According to the embodiment of the invention, therefore, the procedure is so constituted to subject the specific and reference subpixel to conjunction operation that the image smoothing procedure can be done without a sophisticated circuit, with a simple processing, and with finer resolution.

Figs. 15 through 17 are illustrations of circuit block diagrams for the image smoothing describing an embodiment of the present invention for the third image smoothing procedure shown on Figs. 6 through 9B; in which Fig. 15 illustrates the whole circuit block diagram; Fig. 16 illustrates a detailed circuit block diagram for the bordering data generator 30 shown on Fig. 15; and Fig. 17 illustrates detailed circuit block diagram for the boolean logic unit 40 shown on Fig. 15.

Referring Fig. 15, VDATA unfolded in an image RAM (not illustrated) are transferred serially to a shift register 24 synchronizing with a VCLK signal, the VDATA are converted into parallel data in the shift register 24, and the VDATA for a full line of the first scanning line are stored in the first bank of a SRAM memory 25. Repeating sequentially the same procedure, VDATA for the second line are stored in the second bank of the memory 25, VDATA for the third line are stored in the third bank of the memory 25, and so forth, wherein the all of VDATA for the N lines are stored in the 1st through (N)th bank of the memory 25. During the time for preparation of VDATA for the (N+1)th line to be stored in the first address of the (N+1)th bank of the memory 25, an memory control 23 reads sequentially the VDATA stored in the first address of the 1st through (N)th bank on receiving a latch signal, and stores in the latch of a latch & shift register 26A, ..., 26N. Following signals from the memory control 23, the VDATA stored in the latch of the latch & shift register 26A, ..., 26N are loaded into shift registers of the latch & shift register 26A, ..., 26N.

Repeating the same procedure, VDATA for the (N+1)th line are stored in the (N+1)th bank of the memory 25 synchronizing with VCLK, and simultaneously to the above, VDATA for the 1st through (N)th lines stored in the memory 25 are transferred to latches of the latch & shift register 26A, ..., 26N, and then, the VDATA in shift registers of the latch & shift register 26A, ..., 26N are loaded sequentially in a bordering data generator 30 synchronizing with VCLK.

The bordering data generator 30, as shown on Fig. 16, consists of N pairs of bistable triggers or flip-flops F/F311, ..., F/F31N, F/F321, ..., F/F32N which shift the VDATA loaded from the latch & shift register 26A, .., 26N following the VCLK, and X-OR gates 33 (331, ..., 33N) which subject the specific pixel and the bordering pixels to nonequivalence operation, or exclusive OR (E-OR in short) operation as shown on Fig. 6(a).

The procedure of the generator 30 will be that the VDATA loaded in the F/F312 of the first row are transferred to the F/F322 of the second row upon receiving each signal of VCLK signals. The VCLK signals conduct F/F's simultaneously to transfer the VDATA in the F/F322 to the X-OR gate 332B, as well. The potentials, therefore, in front of the F/F312, between the F/F312 and the F/F322, and at rear of the F/F322 correspond to the signals or

logic values of preceding, the specific, and the succeeding pixels, that is, representable the states of A2, B2 and C2 pixels shown on Fig. 6(a).

The output signal XV1 of the X-OR gate 332V corresponds to the bordering data d1, a nonequivalence value with the pixel B1. The output signal XN1 of the X-OR gate 332N corresponds to the bordering data d0, a nonequivalence value with the pixel A2. Further, the output signal XB1 of the gate X-OR 332B corresponds to the bordering data d2, a nonequivalence value with the pixel C2. And lastly, the output signal XV2 of the X-OR gate 333V corresponds to the bordering data d3, a nonequivalence value with the pixel B3.

Thus, the four X-OR gates 332N, 332V, 332B and 333V generate four bits of the bordering data d0, d1, d2 and d3, the nonequivalence values between the specific pixel and the four bordering pixels. Because N pairs of bistable triggers F/F311, .., F/F32N are constituted in the generator 30, the four bits of bordering data d0, d1, d2 and d3 are generated for N vertical pixel lines, and are transferred to the shift register 35 sequentially on each signals of VCLK.

The four bits of bordering data stored in the shift register 35 is shifted to the logic unit 40 together with the information of the specific pixel from the latch & shift register 26C to be subjected to the image smoothing procedure.

Fig. 17 shows a detailed block diagrams of the logic unit 40, which includes a horizontal logic unit 41, a vertical logic unit 42 and a reversion shift register 43. The horizontal logic unit 41 receives any desired lines, 7 lines for example, of the bordering data d0, d1, d2, d3 stored in the shift register 35 for smoothing the stairsteps styled (1) to (4) shown on Fig. 7A, while the horizontal logic unit 42 receives the desired rows, 7 rows for example, of the bordering data for smoothing the stairsteps styled (5) to (8) shown on Fig. 7B. The reversion shift register 43 reverses the subpixels corresponding to the information generated with the logic units 41 and 42.

The horizontal logic unit 41 further includes: the first stairstep detector 44 for detecting the stairsteps (1) and (2) shown on Fig. 7A; the second stairstep detector 45 for detecting the stairsteps (3) and (4); a reversion code detector 46 for measuring the length of level pixels with respect to the detected stairstep, and for assigning pixel(s) with its reversion code referring to the reversion code table; and a reversion decoder 47 for assigning subpixel(s) to be reversed referring to the reversion data table.

The reversion decoder 47 has been installed with the reversion data table shown on Fig. 8(b) made of memories or random logics. The reversion decoder 47, hence as previously described, is able to refer to the table with the style of stairstep ((1) or to (8)), and the reversion code (1 or 2) for assigning which of the subpixel(s) will be reversed.

Similar to the horizontal logic unit 41, the vertical logic unit 42 consists of the first stairstep detector 44' for detecting stairsteps (5) and (6), the second stairstep detector 45' for detecting stairsteps (7) and (8), the reversion code detector 46', and the reversion decoder 47', for which no further detailed procedures is described, as it works similarly to the horizontal logic unit 41.

From the latch & shift register 26C, the reversion shift register 43 receives serially the VDATA for one scanning line for four times repeatedly corresponding to the pixel division number of (four) subpixels. The VDATA stored in the reversion shift register 43 are reversed with the signals corresponding to the VDATA pixels from the logic units 41 and 42 for reversion as desired to be transferred to the LED head.

Referring Figs. 9A and 9B, the reversion procedure will be described as follow:

The VDATA shown on Fig. 9A (A) are transferred from the latch & shift register 26A, ..., 26N into the bordering data generator 30 which generates the bordering data d0, d1, d2, d3 to be stored in the shift register 35.

The logic unit 40 receives the bordering data d0, d1, d2, d3 stored in the shift register 35, and the corresponding pixels to be modified from one of the latch & shift register, 26C for example. The stairsteps and its style are detected with the stairstep detector 44, 45 analyzing the bordering data d0, d1, d2, d3.

In the event when the stairstep(s) is detected, the reversion code detector 46 measures the length of level pixels as shown on Fig. 9A (C), and then assigns the pixel(s) with the reversion code referring to the reversion code table with the style of stairstep and the length of level pixel as shown on 9B (A).

On receiving the style of stairstep and the reversion code, the reversion decoder 47 assigns which part of the subpixel(s) will be reversed referring to the reversion data table, and then output the reversion signals to the reversion shift register 43 as shown on Fig. 9B (B).

Lastly, the pixel in the reversion shift register 43 are subjected to reversion procedure conducted with the reversion signals from the reversion decoder 47 as shown on Fig 9B (C).

Claims

1. A method for smoothing an image by reversing subpixel signal(s) as desired, which subpixel is a divisional part of a pixel, including white or black pixels which form an image pattern in a

matrix, the method comprising the steps of:

selecting a specific pixel to be smoothed with the information of pixels bordering the specific pixel,

reversing one or a plurality of signals to be applied to the subpixel(s) of the specific pixel.

2. The method of claim 1, wherein the smoothing procedure is subjected to reverse a group of subpixels N or a vacant pixel as desired, which vacant subpixel is disposed at each end of the group of subpixels N, while the image signal is applied to the group of subpixels N for the normal image output.

3. The method of claim 1, wherein the smoothing procedure is conducted to reverse one or a plurality of subpixels selected from a group of subpixels P, while the image signal is applied to a group of subpixels N ($N < P$) for the normal image output.

4. The method of claim 1, wherein the subpixels-(s) is/are so reversed as desired that the location of subpixel(s) seemingly shifts in the direction of the scanning line, or that the size or diameter of the subpixels seemingly changes in the direction of the scanning line.

5. The method of claim 4, wherein the reversion of a subpixel is conducted with the subpixel(s) as desired within the constitution of the pixel so that the location of the subpixel(s) seemingly shifts in the desired scanning direction, or that the size or diameter of the subpixels seemingly changes in the desired scanning direction.

6. The method of claim 4, wherein the reversion of a subpixel is conducted with the subpixel(s) as desired up to the subpixel(s) of the bordering pixel so that the location of subpixel(s) seemingly shifts in the desired scanning direction, or that the size or diameter of the subpixels changes in the desired scanning direction.

7. A method for smoothing an image by reversing subpixel signal(s) as desired, which subpixel is a divisional part of a pixel, including white and black pixels, which form an image pattern in a matrix, the method comprising the steps of:

subjecting a specific pixel and one or a plurality of bordering pixels to a conjunction operation, or to a combination of conjunction and disjunction operations, in which the specific pixel is located at the stairstep where a white pixel(s) turns to a black pixel(s), or a black pixel(s) turns to a white pixel(s), wherein the specific pixel adjoins the bordering pixel located on the preceding or succeeding scanning line,

reversing, as desired, the subpixel(s) of the specific pixel, the bordering pixel(s) or pixel(s) adjoining the bordering pixel.

8. The method of claim 7, wherein the specific pixel and the bordering pixel located on the preceding, or the succeeding scanning line are subjected to a conjunction operation for assigning subpixel(s) to be reversed, and wherein the subpixel(s) between the specific subpixel and the assigned subpixel reverses spontaneously as well.

9. A method for smoothing an image for reversing subpixel signal(s) as desired, which subpixel is a divisional part of a pixel, including white or black pixels which form an image pattern in a matrix, the method comprising the steps of:

generating a bordering datum representing the relationship between any specific pixel and a bordering pixel adjoining the specific pixel,

specifying the location of a stairstep and the style of the stairstep with the relationship of the bordering data of pixels located on the desired scanning line in the horizontal or vertical direction,

measuring the length of level pixels adjacent to the specific pixel,

reversing subpixel(s) as desired corresponding to said data to form the image output.

10. The method of claim 9, wherein bordering data of four bits of binary values are generated by subjecting each of specific pixel and the four bordering pixels to a nonequivalence operation, in which the bordering pixels adjoin the specific pixel located on preceding or succeeding lines, and at the right or left on the same line.

11. The method as claimed in claim 9, wherein, in the bordering data for more than three pixels extracted from pixels adjoining the specific pixel horizontally or vertically in a line, the relationship among the bordering data for a pair of the adjoining pixels, denoted d0A, ..., d3A and d0B, ..., d3B, and assumed (α and β) as any one of combinations among (0, 1), (1, 2), (2, 3) and (3, 0), will be

$$(d\alpha A, d\alpha B) = (d\beta A, d\beta B) = (0, 1), \quad \text{Equ. 1}$$

wherein, assuming τ or δ are any other numerals designating the bordering data for

the pixel A taken in Equation 1), the rest of the bordering data for the pixel A will be

$$d_{\tau}A = d_{\delta}A = 1, \quad \text{Equ. 2)}$$

wherein the relationship within the bordering data for the pixel C opposite to the pixel B next to the pixel A, and assuming τ or δ are any other numerals taken in the Equation 1), will be

$$(d_{\tau}C, d_{\delta}C) = (1, 0) \text{ or } (0, 1), \quad \text{Equ. 3)}$$

and wherein, if the relationship among the bordering data for the three pixels, A, B, and C, satisfy simultaneously at least the three equations, Equs. 1), 2) and 3), the boundary between A and B is deciphered as the stairstep.

12. The method of claim 11, wherein the style of the stairstep is recognized with the three equations, Equs. 1), 2) and 3).

13. The method of claim 9, wherein a reversion code is assigned to each pixel according to the distance from the stairstep and to the length of level pixels, in which the reversion code represents which of the subpixel(s) is reversed for each style of the stairsteps.

FIG. 1
(a)

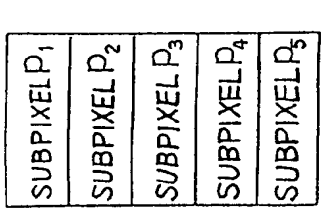

SUBPIXEL P1
SUBPIXEL P2
SUBPIXEL P3
SUBPIXEL P4
SUBPIXEL P5
PIXEL

FIG. 1
(b)

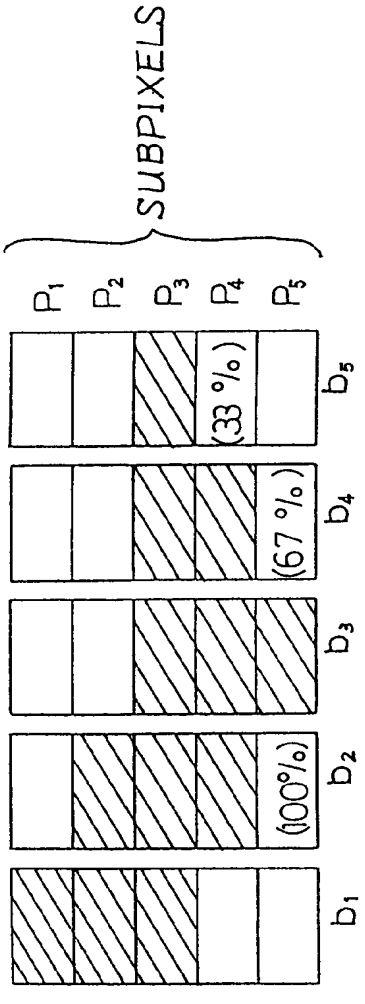

SUBPIXELS
P1
P2
P3
P4
P5
(100%)
(67 %)
(33 %)
b1
b2
b3
b4
b5

FIG. 2 (a)

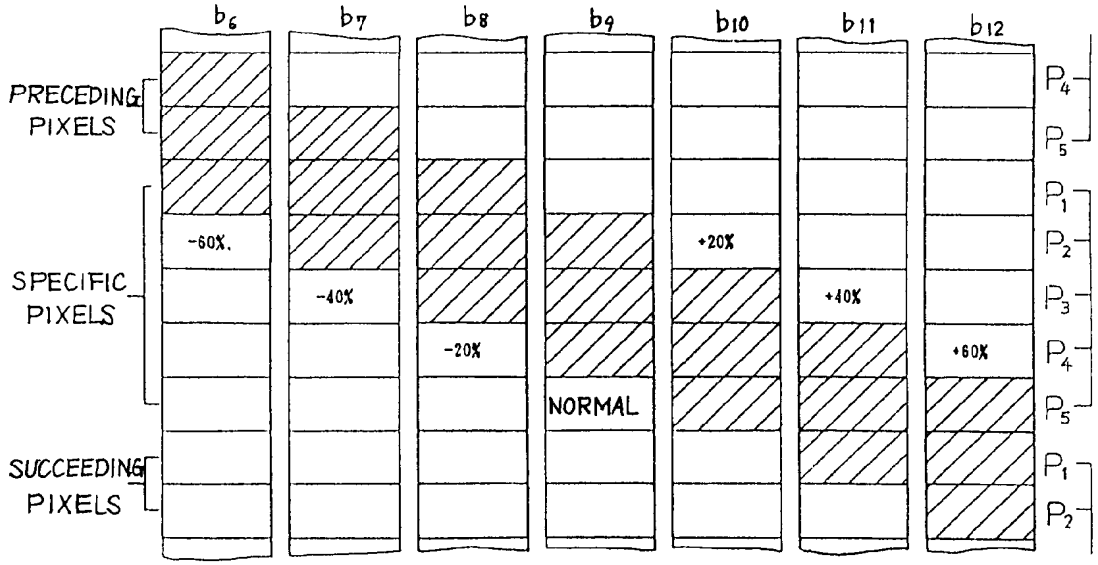

b6
b7
b8
b9
b10
b11
b12
PRECEDING PIXELS
SPECIFIC PIXELS
SUCCEEDING PIXELS
-60%
-40%
-20%
NORMAL
+20%
+40%
+60%
P4
P5
P1
P2
P3
P4
P5
P1
P2

FIG. 2 (b)

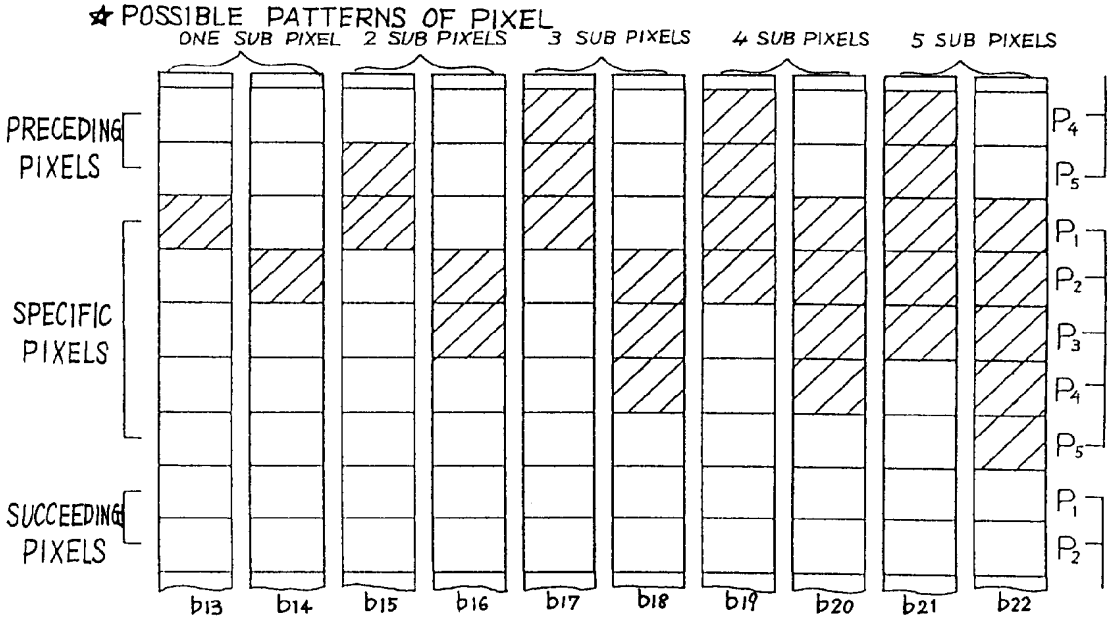

☆ POSSIBLE PATTERNS OF PIXEL
ONE SUB PIXEL
2 SUB PIXELS
3 SUB PIXELS
4 SUB PIXELS
5 SUB PIXELS
PRECEDING PIXELS
SPECIFIC PIXELS
SUCCEEDING PIXELS
P4
P5
P1
P2
P3
P4
P5
P1
P2
b13
b14
b15
b16
b17
b18
b19
b20
b21
b22

FIG. 3 (a)

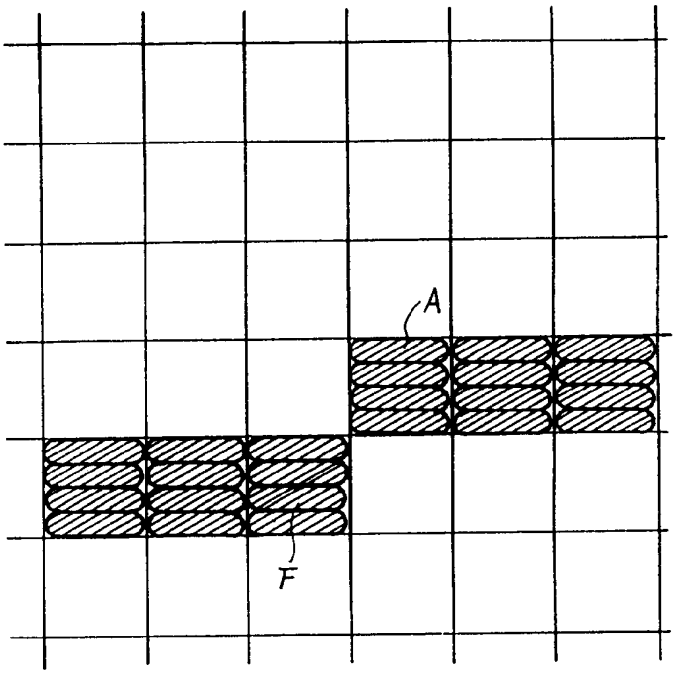


FIG. 3 (b)

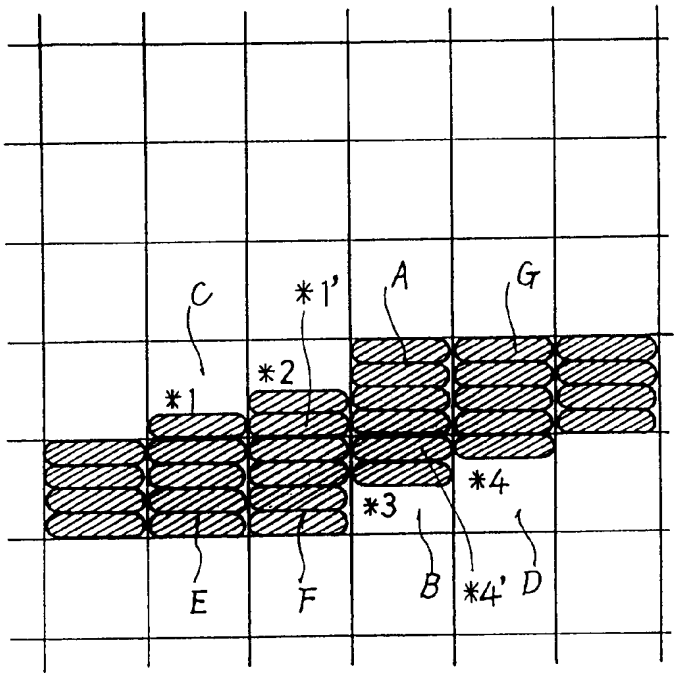


FIG. 4 (a)

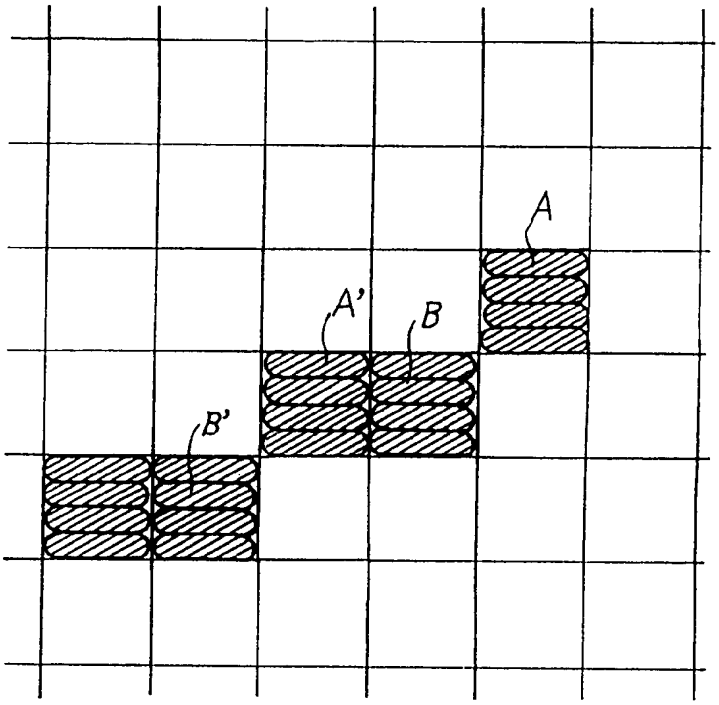


FIG. 4 (b)

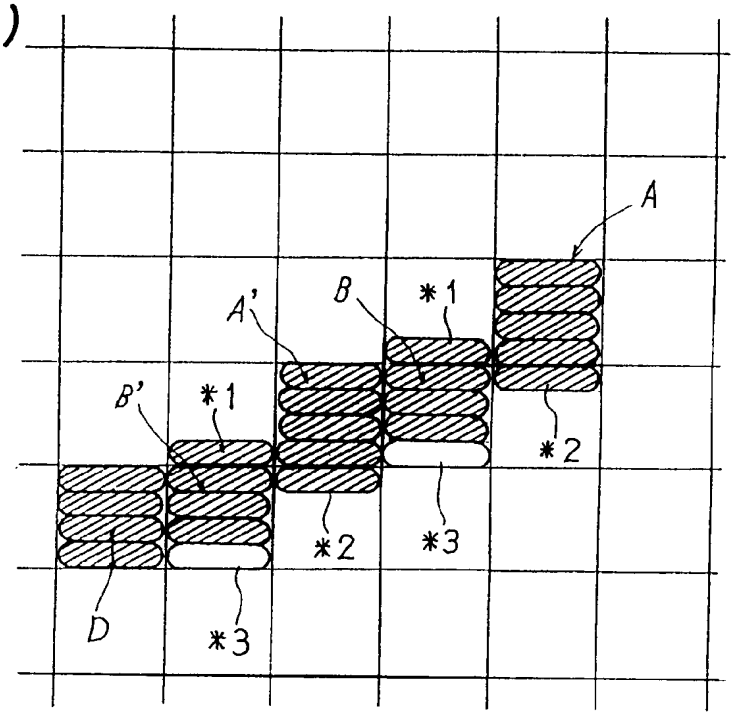


FIG. 5

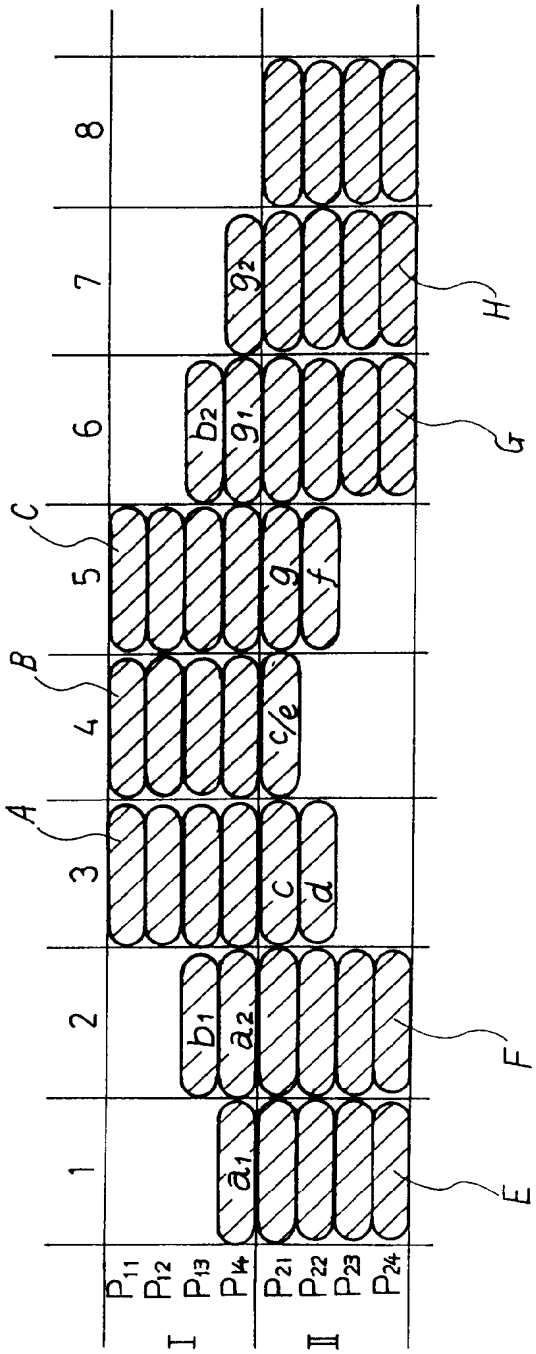

1
2
3
4
5
6
7
8
A
B
C
G
H
E
F
a_1
b_1
a_2
c
d
c/e
g
f
b_2
g_1
g_2
P_{11}
P_{12}
P_{13}
P_{14}
P_{21}
P_{22}
P_{23}
P_{24}
I
II

FIG. 6 (a)

SHIFTING DIRECTION →

(n-1) line	A1 (n-1)	B1 (n-1)	C1 (n-1)	
n line	A2 n	B2 n	C2 n	
(n+1) line	A3 (n+1)	B3 (n+1)	C3 (n+1)	

FIG. 6 (b)

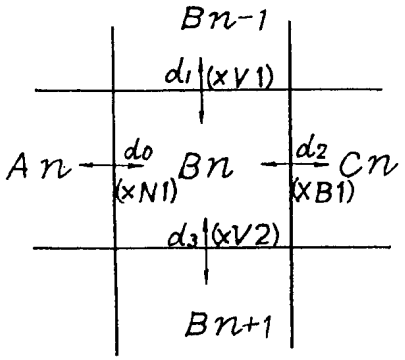
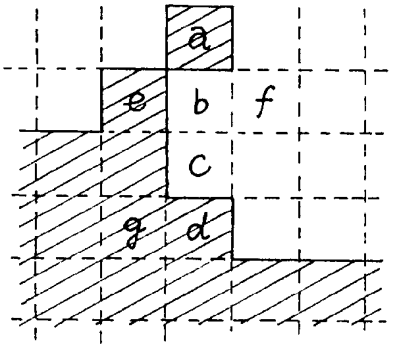


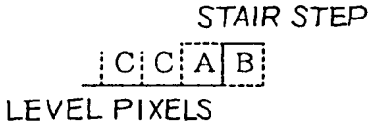
FIG. 6 (c)



	a	b	c	d	e	f	g
do	1	1	1	0	1	0	0
d1	1	1	0	1	1	0	0
d2	1	0	0	1	1	0	0
d3	1	0	1	0	0	0	0

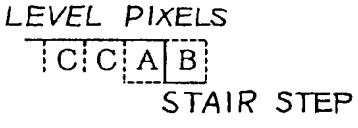
FIG. 7 A

①



	C	A	B
d_0	*	0	1
d_1	*	0	1
d_2	0	1	*
d_3	1	1	*

②

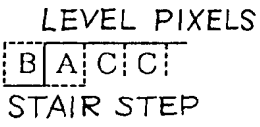


	C	A	B
d_0	*	0	1
d_1	1	1	*
d_2	0	1	*
d_3	*	0	1

③

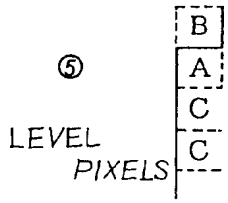
	B	A	C
d_0	*	1	0
d_1	1	0	*
d_2	1	0	*
d_3	*	1	1

④

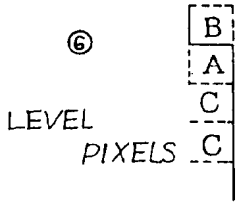


	B	A	C
d_0	*	1	0
d_1	*	1	1
d_2	1	0	*
d_3	1	0	*

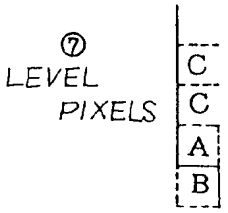
FIG. 7 B



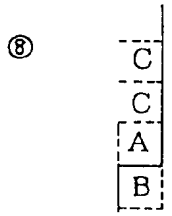
	d_0	d_1	d_2	d_3
B	*	*	1	1
A	1	1	0	0
C	1	0	*	*



	d_0	d_1	d_2	d_3
B	1	*	*	1
A	0	1	1	0
C	*	0	1	*



	d_0	d_1	d_2	d_3
C	1	*	*	0
A	1	0	0	1
B	*	1	1	*



	d_0	d_1	d_2	d_3
C	*	*	1	0
A	0	0	1	1
B	1	1	*	*

FIG. 8

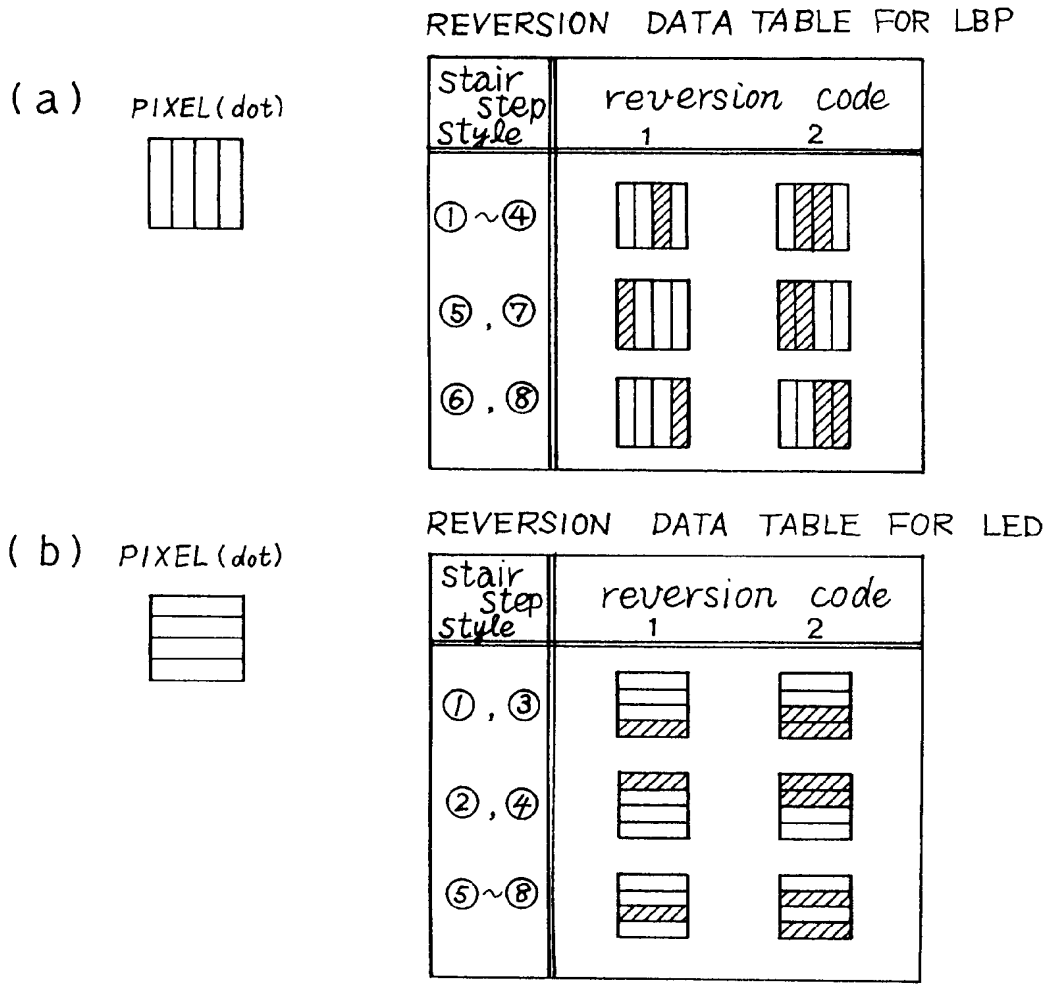

REVERSION DATA TABLE FOR LBP
(a)
PIXEL (dot)
stair step style
reversion code
1
2
①~④
⑤, ⑦
⑥, ⑧
REVERSION DATA TABLE FOR LED
(b)
PIXEL (dot)
stair step style
reversion code
1
2
①, ③
②, ④
⑤~⑧

FIG. 9 A

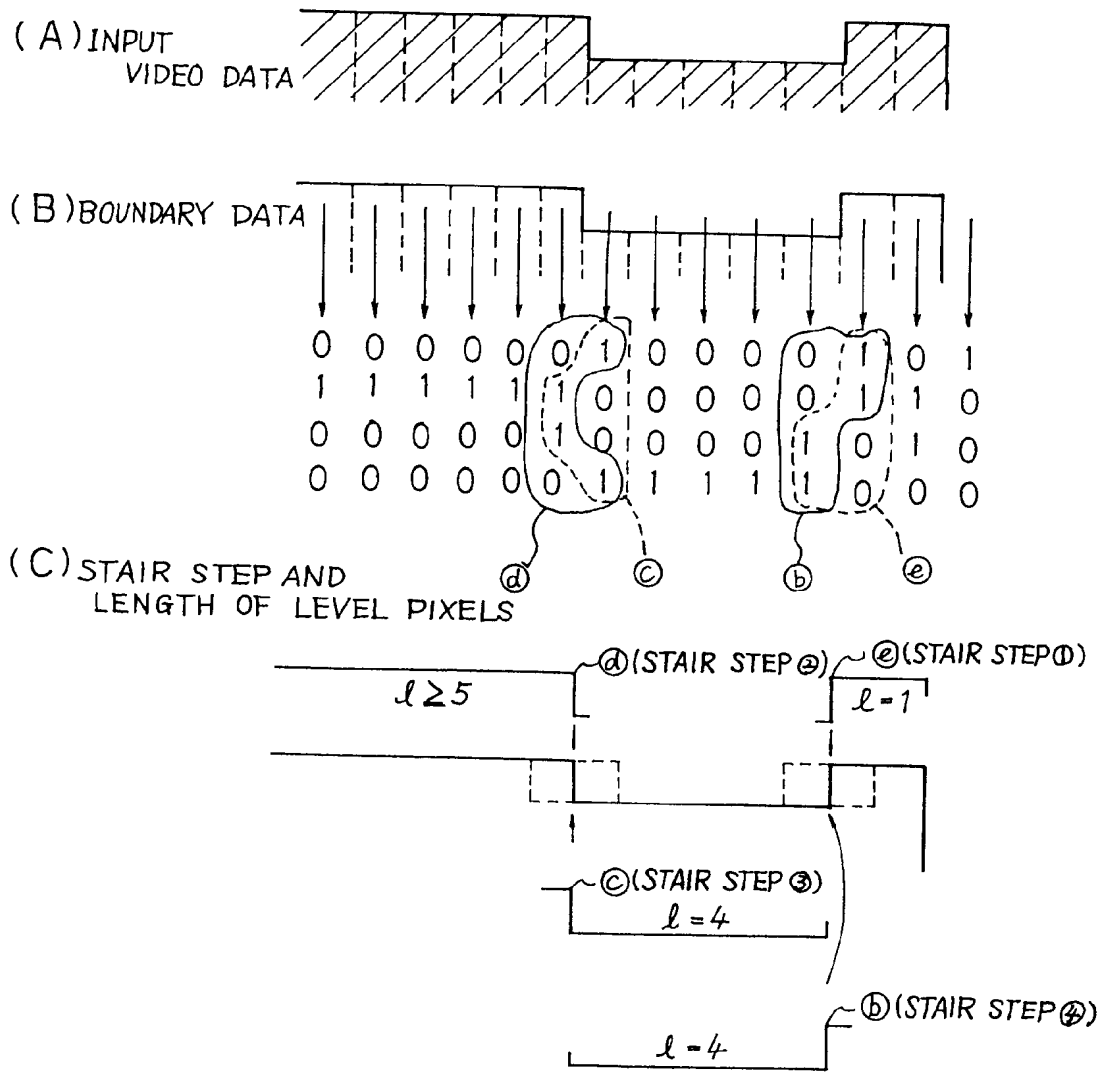
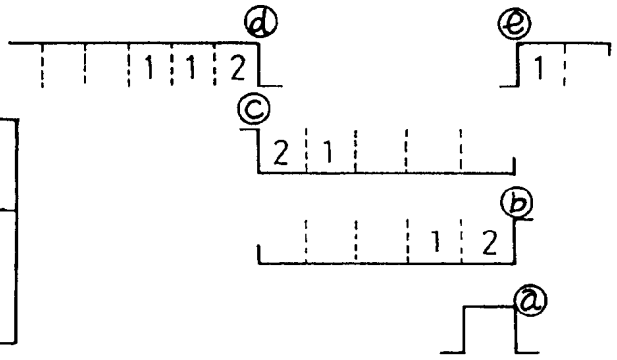

(A) INPUT VIDEO DATA
(B) BOUNDARY DATA
0 0 0 0 0 0 1 0 0 0 0 1 0 1
1 1 1 1 1 1 0 0 0 0 0 1 1 0
0 0 0 0 0 1 0 0 0 0 1 0 1 0
0 0 0 0 0 0 1 1 1 1 1 0 0 0
ⓓ ⓒ ⓑ ⓔ
(C) STAIR STEP AND LENGTH OF LEVEL PIXELS
ℓ ≥ 5
ⓓ (STAIR STEP ②)
ⓔ (STAIR STEP ①)
ℓ = 1
ⓒ (STAIR STEP ③)
ℓ = 4
ⓑ (STAIR STEP ④)
ℓ = 4

FIG. 9 B

(A) REVERSION CODE

REVERSION CODE TABLE

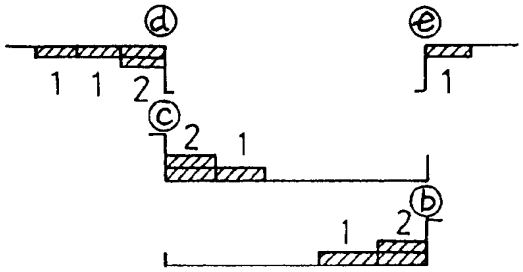
PIXEL APART FROM STAIRSTEP	LENGTH OF LEVEL PIXELS 1	2	3	4	5
0	1	1	2	2	2
1			1	1	1
2					1



(B) REVERSION DATA

REVERSION DATA TABLE

Stair Step Style		REVERSION CODE 1	2
①,③	ⓑ,ⓒ	□	▨
②,④	ⓓ,ⓔ	□	▨



(C) REVERSION OF SUBPIXELS

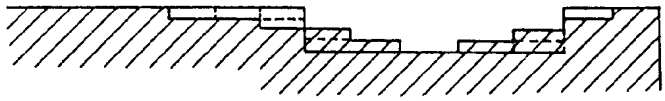


FIG.10

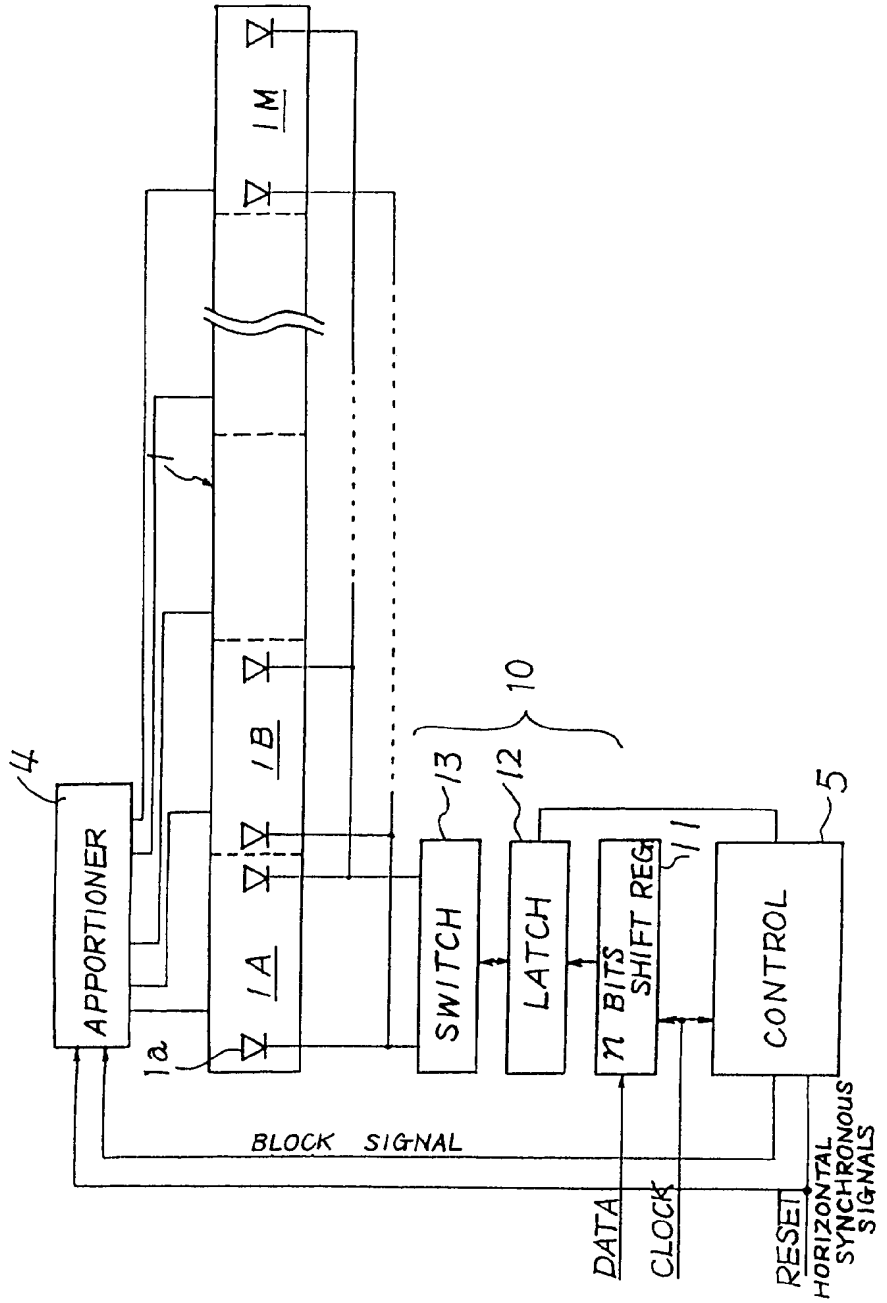

4
APPORTIONER
1a
1A
1B
1M
10
13
12
11
5
SWITCH
LATCH
n BITS SHIFT REG
CONTROL
BLOCK SIGNAL
DATA
CLOCK
RESET
HORIZONTAL SYNCHRONOUS SIGNALS

FIG. 11

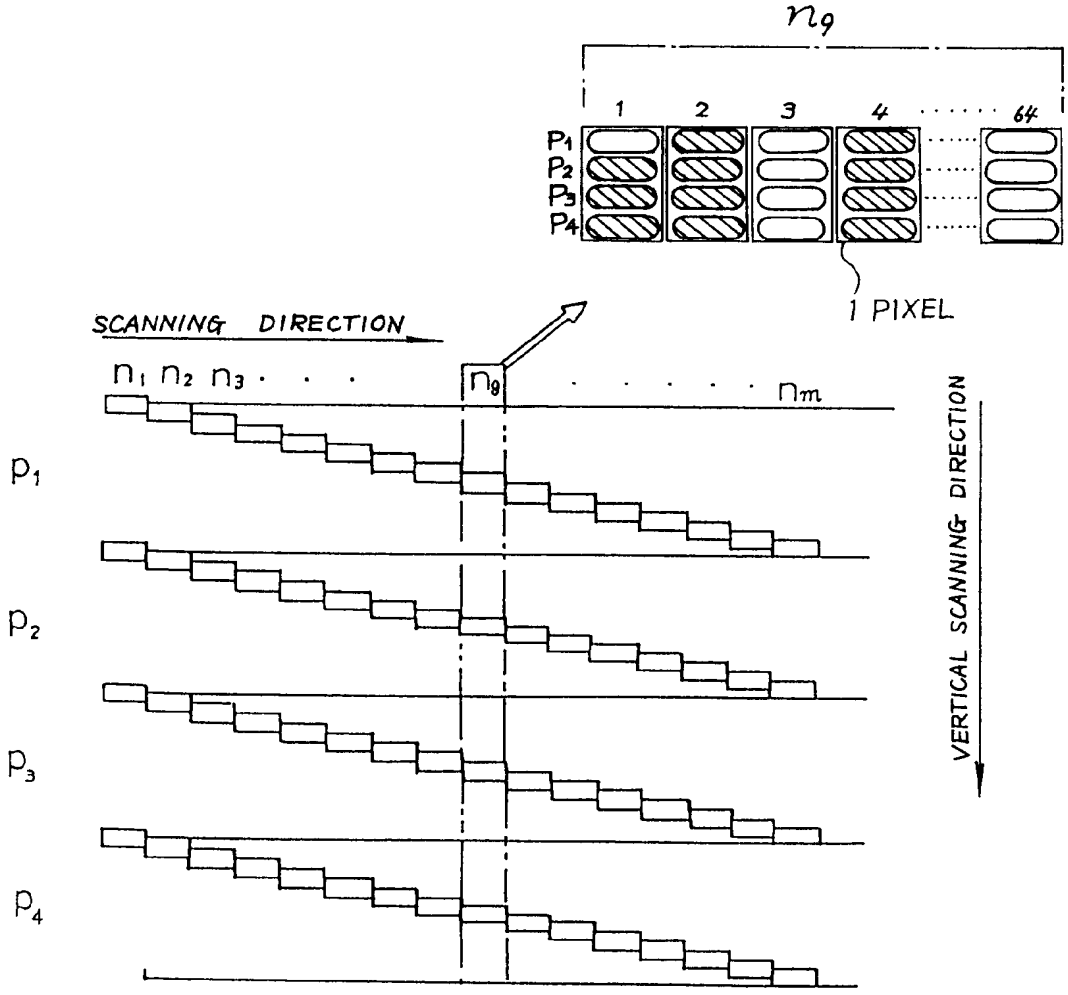

n_9
1
2
3
4
64
P_1
P_2
P_3
P_4
1 PIXEL
SCANNING DIRECTION
n_1 n_2 n_3 . . .
n_9
. . . . . n_m
p_1
p_2
p_3
p_4
VERTICAL SCANNING DIRECTION

FIG.12 (a)

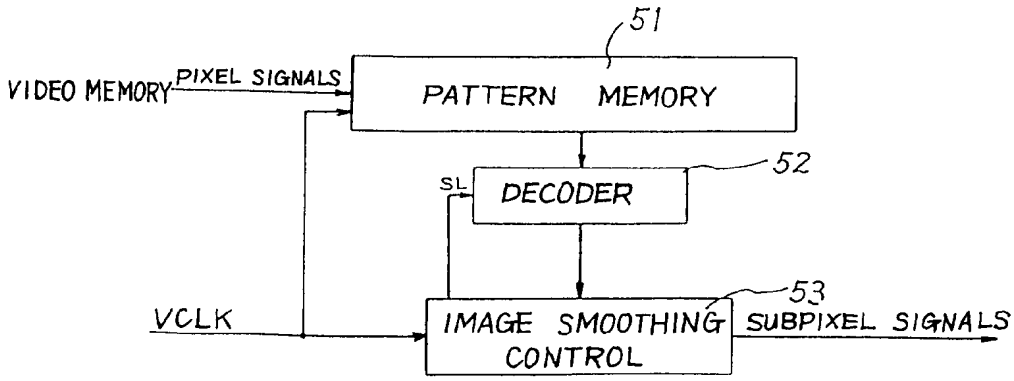


FIG.12 (b)

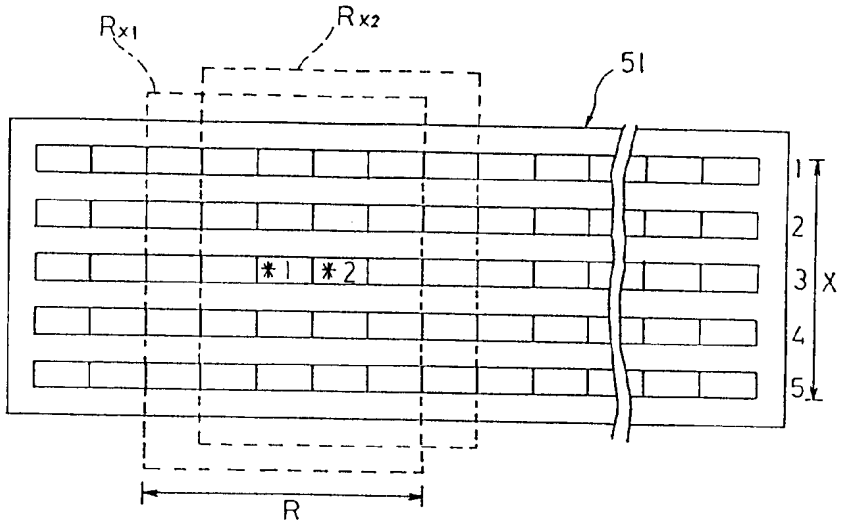


FIG.13

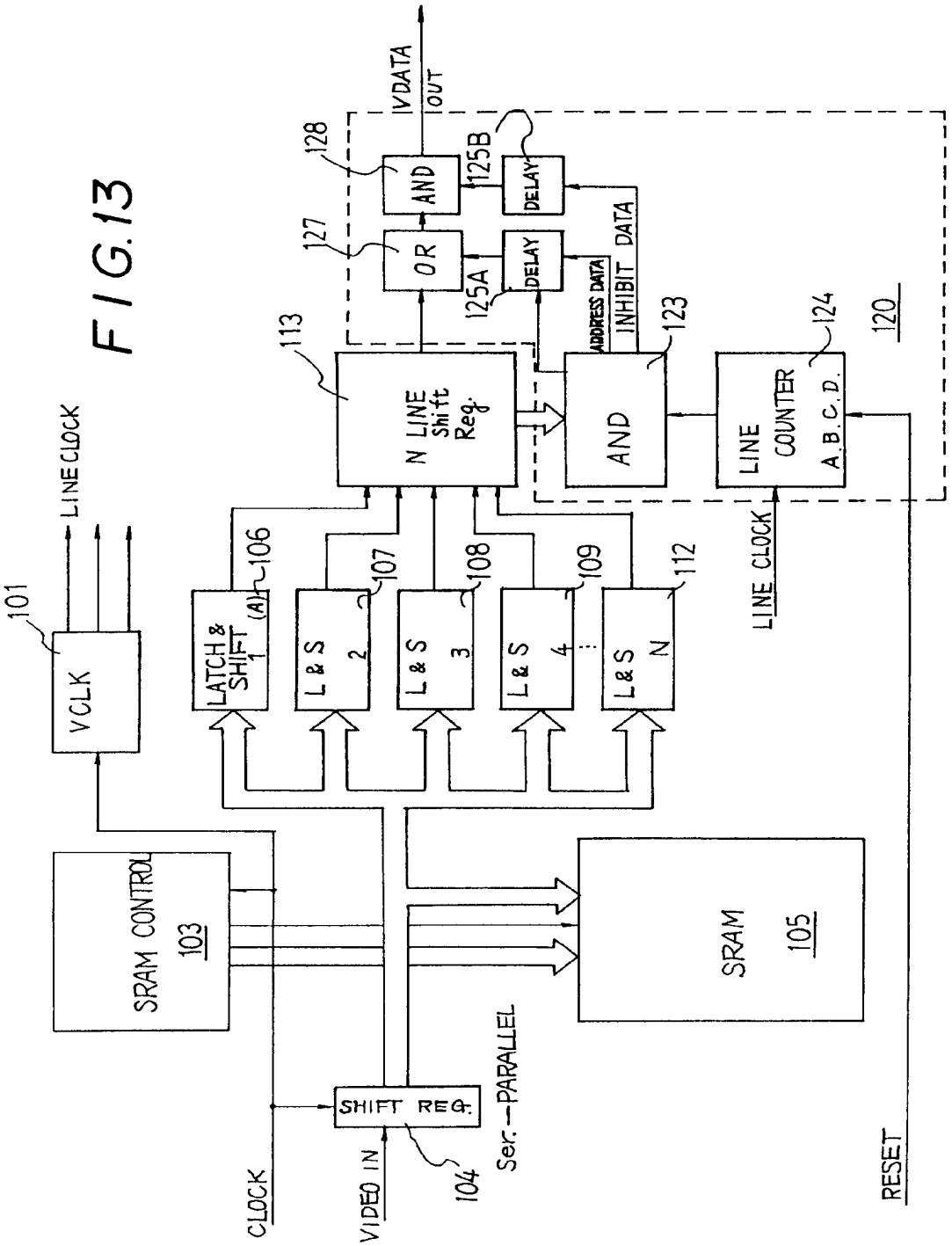
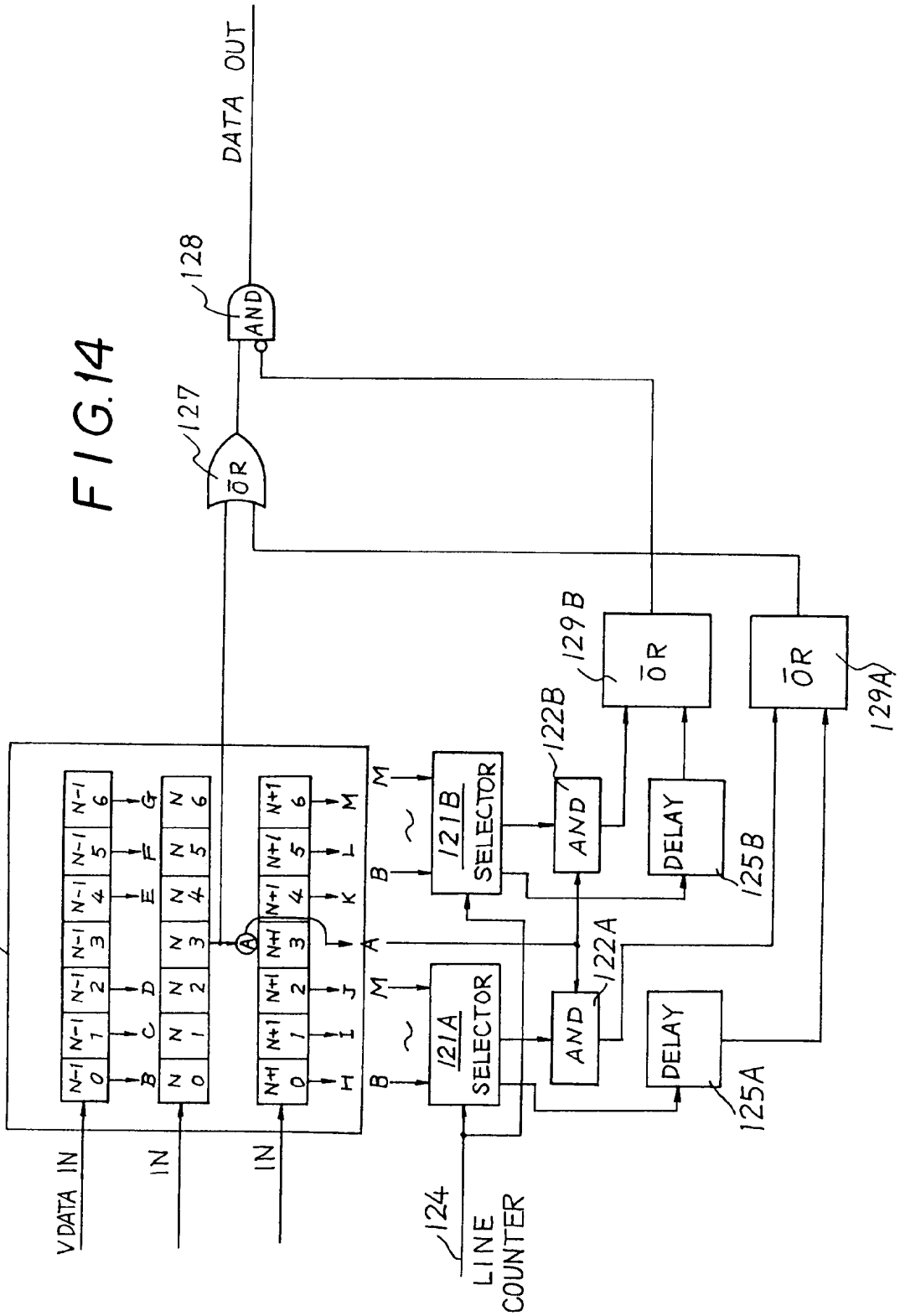

IVDATA OUT
128
AND
125B
DELAY
127
OR
125A
DELAY
ADDRESS DATA
INHIBIT DATA
113
N LINE Shift Reg.
AND
123
LINE COUNTER A.B.C.D.
124
120
LINE CLOCK
LINE CLOCK
101
VCLK
LATCH & SHIFT 1 (A)
106
L & S 2
107
L & S 3
108
L & S 4
109
L & S N
112
SRAM CONTROL 103
SRAM 105
SHIFT REG.
104
Ser.—PARALLEL
CLOCK
VIDEO IN
RESET

FIG.14


DATA OUT
128
AND
127
OR
129B
OR
129A
OR
122B
AND
122A
AND
121B
SELECTOR
121A
SELECTOR
125B
DELAY
125A
DELAY
113
VDATA IN
IN
IN
124
LINE COUNTER
N-1 0
N-1 1
N-1 2
N-1 3
N-1 4
N-1 5
N-1 6
N 0
N 1
N 2
N 3
N 4
N 5
N 6
N+1 0
N+1 1
N+1 2
N+1 3
N+1 4
N+1 5
N+1 6
A
B
C
D
E
F
G
H
I
J
K
L
M

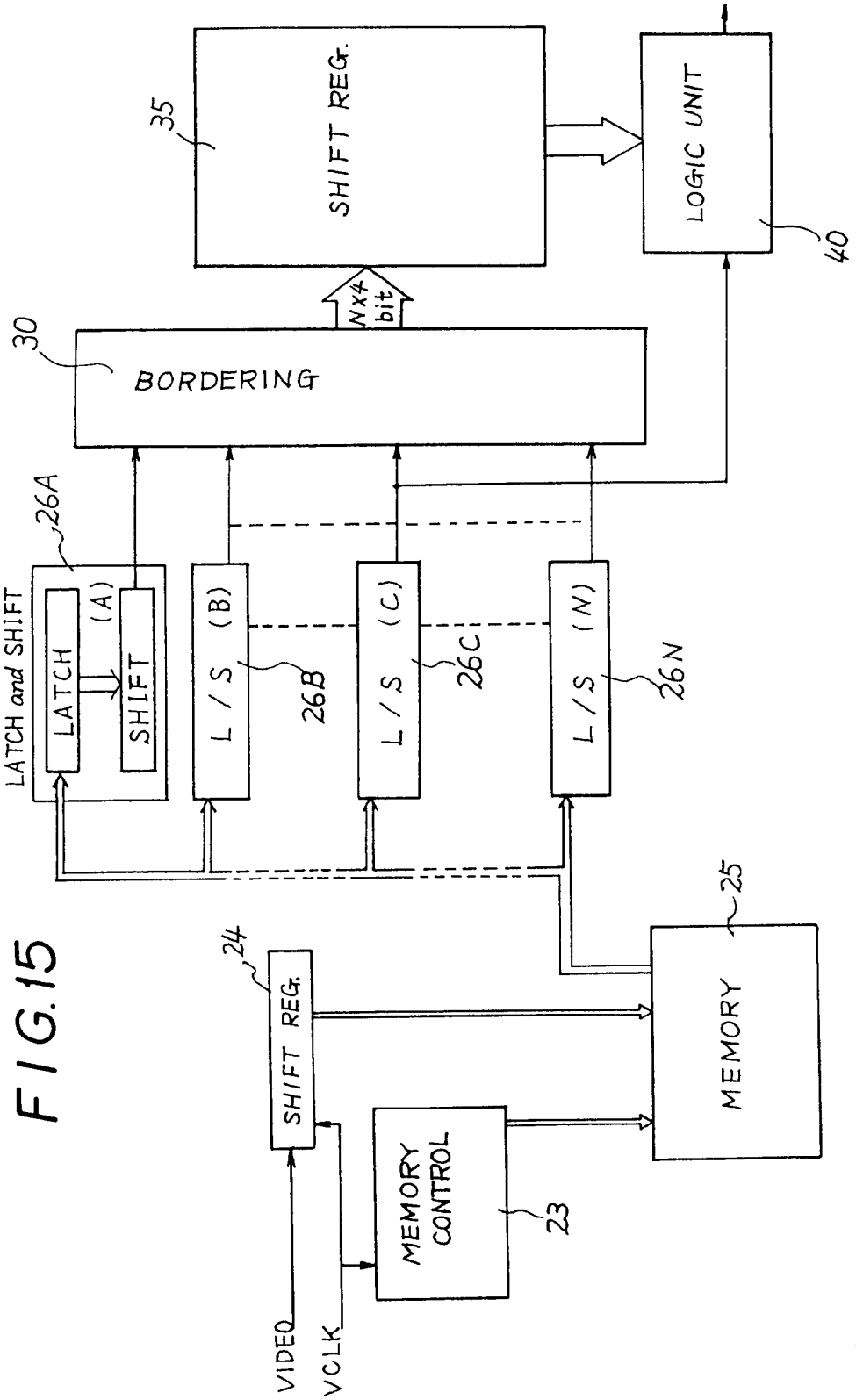

35
SHIFT REG.
LOGIC UNIT
40
Nx4 bit
30
BORDERING
26A
LATCH and SHIFT
LATCH
(A)
SHIFT
L/S (B)
26B
L/S (C)
26C
L/S (N)
26N
24
SHIFT REG.
25
MEMORY
MEMORY CONTROL
23
VIDEO
VCLK

FIG.15

FIG.16

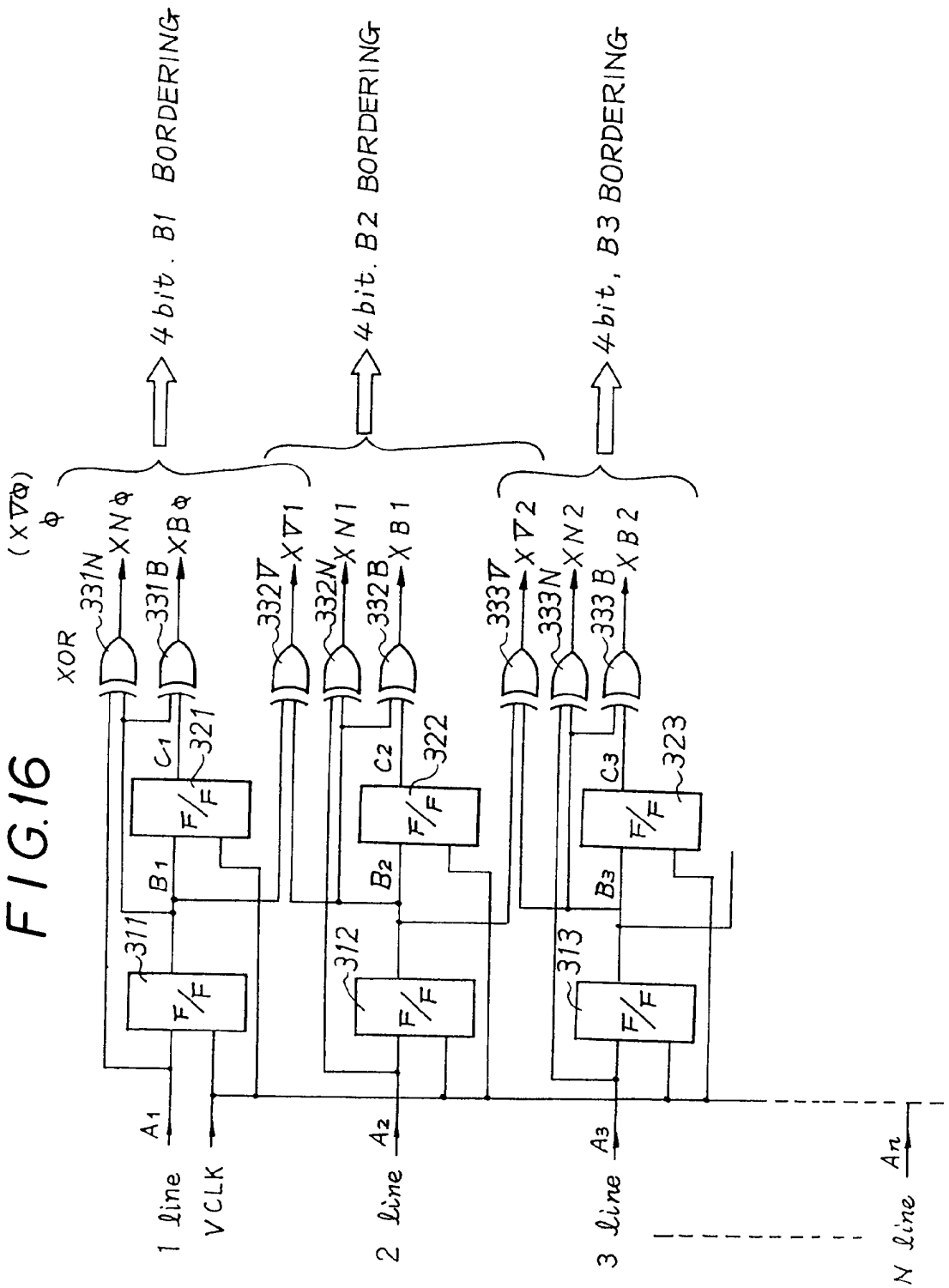
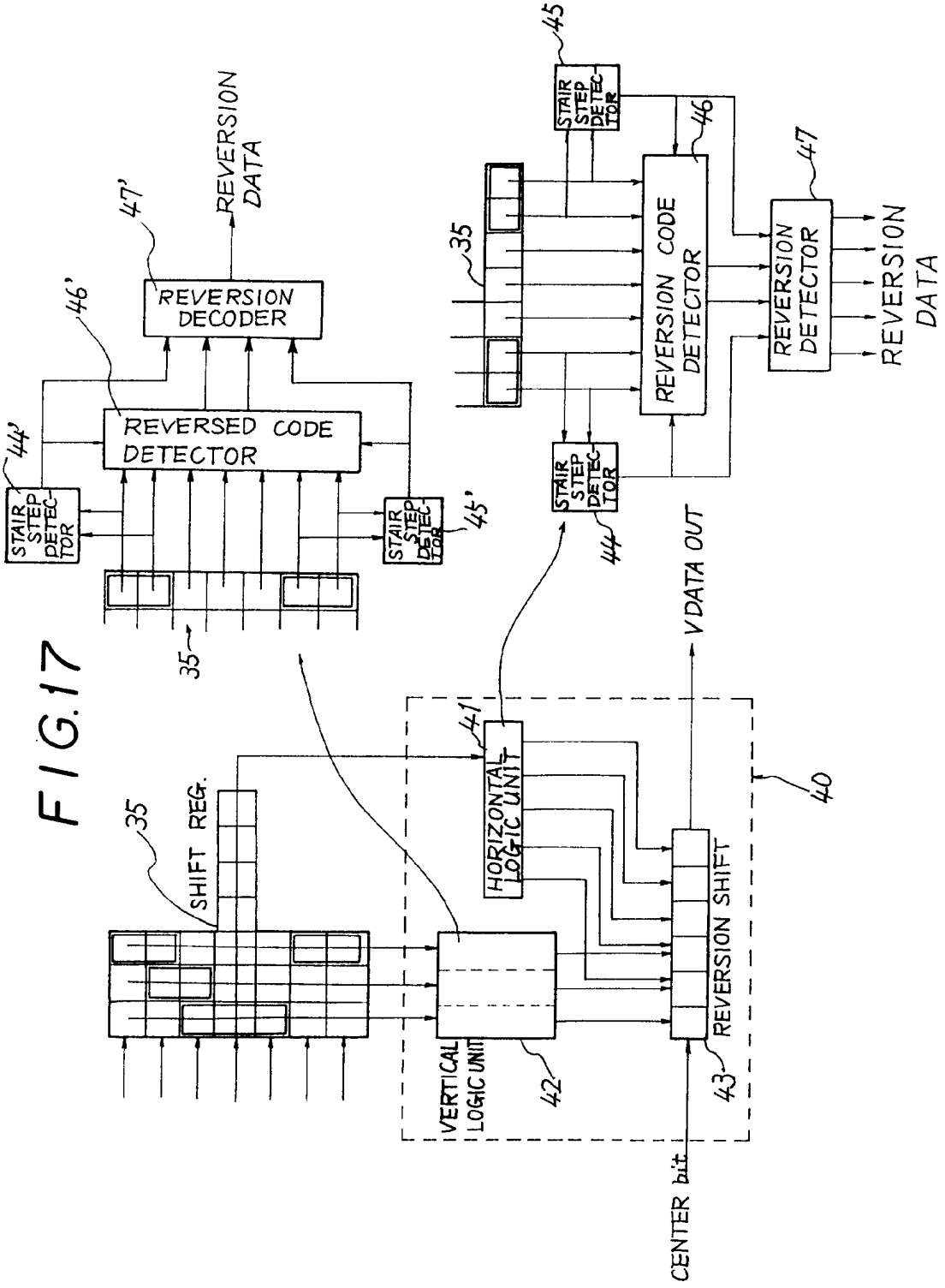

4 bit. B1 BORDERING
4 bit. B2 BORDERING
4 bit, B3 BORDERING
(X∇Φ)
Φ
XOR
331N
XNΦ
331B
XBΦ
332∇
X∇1
332N
XN1
332B
XB1
333∇
X∇2
333N
XN2
333B
XB2
311
312
313
321
322
323
C1
C2
C3
B1
B2
B3
F/F
A1
A2
A3
An
1 line
2 line
3 line
N line
VCLK

FIG.17


35
SHIFT REG.
VERTICAL LOGIC UNIT
42
HORIZONTAL LOGIC UNIT
41
REVERSION SHIFT
43
40
CENTER bit
V DATA OUT
STAIR STEP DETECTOR
44'
45'
46'
47'
REVERSED CODE DETECTOR
REVERSION DECODER
REVERSION DATA
35
STAIR STEP DETECTOR
44
45
REVERSION CODE DETECTOR
46
REVERSION DETECTOR
47
REVERSION DATA